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MECHANICAL ENGINEERING

April 1932

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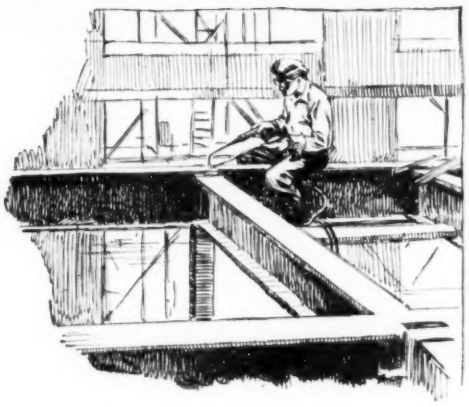

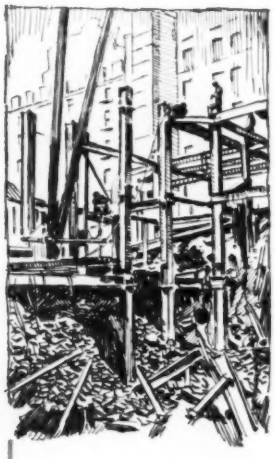

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MECHANICAL ENGINEERING

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WHAT IT'S ALL ABOUT

VIEWING the contemporary scene in what perspective is permitted to them, many thoughtful engineers see in it and the future greater opportunities and responsibilities for themselves and their fellow-practitioners. Science and technology have changed the world, its thoughts, and its habits, and themselves undergo changes through growth and the development of new functions to perform for society. With an increasing understanding of the relation of science and engineering to modern life, engineers are viewing the future with new interest and zeal.

In MECHANICAL ENGINEERING this month have been gathered together a number of papers that reflect some of this thinking. A common thread of opportunity and progressiveness runs through them, and they emphasize the broadening interests and functions of the engineer and his dependence upon the valued tool of research. They form an appropriate follow-up of the stimulating discussion of the need for the research method in dealing with social and economic ills presented last month in Mr. Hirshfeld's article "Whose Fault?"

FREDERICK LANE HUTCHINSON

(Since 1911 National Secretary of the American Institute of Electrical Engineers, whose death occurred on February 26, 1932.)

DR. JEWETT'S article this month, "Problems Confronting the Engineering Profession," establishes contact with Mr. Hirshfeld's of last month when it says that engineers have not taken the same part in the evolution of society that they must take in the future. With the engineer engaging in this enlarged function, three major problems, which Dr. Jewett discusses, present themselves: the education of the engineer, with more emphasis on the social aspects of his job; the education of the rank and file of citizens, who must have a better understanding of the fundamentals of science and engineering in order to avoid the pitfalls of ignorance that beset social progress; and the technical society, which must equip itself to play its part in directing the understanding of its members on the technical phases of the problems of the world.

Dr. Jewett sees the technical point of view as being changed in two respects: we are reaching the limit of ultimate possibility in the applications of science in some fields, and we have an increasing need for a more certain and ultimate knowledge of materials.

RESEARCH, then, is to play, as it has in the past, an important part in the future. John P. Ferris follows up this idea in his article on "Research for Industrial Pioneering." While invention played an important part in the last two centuries, organized invention, or research, offers the most fertile source of new ideas for the future and, in industry, opens up new fields of progress.

We are today, Mr. Ferris points out, faced with the necessity of bringing out and getting into circulation new industrial ideas that now lie buried. He even suggests a few problems awaiting the solution that research may provide. He sees industry served by large, well-manned, and well-organized laboratories, and sets up a policy for university research activities: i.e., to do something that will not be well done or done at all if left to private industry, to minimize duplication of research activities, and to do something that is socially desirable and needs to be done. Mr. Ferris points to the Engineering Foundation as the agency capable of exercising an intelligent coordinating and directive influence on engineering research.

CARRYING to its logical conclusion the inference that the engineers can provide the material elements of progress, R. E. Flanders, in an article entitled "Engineering, Investment, and Social Well-Being," analyzes the social and economic aspects of savings and investments, and shows that it is the business of the engineer to discover and develop all possible opportunities for profitable new investment. The dependence of the financial structure on the engineer, says Mr. Flanders, will become more definite as time goes on.

The easy and obvious fields for investment are being

worked out, the mechanism of industrial civilization is nearing completion. As an increasing flood of savings seeks profitable investment, to serve society as a whole, the burden of finance will rest more heavily upon the shoulders of the engineer. Such is the importance of engineering and engineering research to the investment market and to the prosperity of the country.

WITH the broad opportunities and obligations laid before engineers in the papers by Jewett, Ferris, and Flanders, in which research plays so important a part, it is only proper that a few examples of work in progress should be given. Herbert N. Eaton contributes the first of two articles on the National Hydraulic Laboratory at the Bureau of Standards. Hydraulic engineers have been interested in this project for years, and rejoice in the fact that the long-anticipated laboratory is at last a reality. Mr. Eaton discusses briefly some of the European laboratories in explaining the reasons for designing a laboratory of the indoor rather than the outdoor type, for providing both a large amount of unobstructed floor space and a considerable amount of fixed equipment, and for making it possible to circulate large quantities of water—features that distinguish our National Hydraulic Laboratory.

TURNING from a national laboratory to the work of a professional society in aiding engineering research, we find an article by A. E. Flowers and M. D. Hersey on the "Lubrication Research of The American Society of Mechanical Engineers." The statement was prepared for a lubrication congress held in Strasbourg, France, last summer. An impressive bibliography indicates what a rich literature on lubrication exists in the publications of the A.S.M.E. as the result of its special research committee organized in 1915.

AN INTERESTING example of a research conducted at a university for an industrial establishment is found in the paper by Messrs. Firestone, Durbin, and Abbott, entitled "Reducing Noise of Machines." The investigation was carried out at the University of Michigan for the purpose of developing a soundmeter for the routine noise inspection of cream separators. It is earnestly to be hoped that manufacturers of machinery generally will find it possible to develop similar means of noise inspection, with the result that fewer needlessly noisy machines will be turned loose in an already too noisy world.

READERS of MECHANICAL ENGINEERING are familiar with the research in the thermal properties of steam that for many years has engaged the attention of workers under the guidance of a committee of the A.S.M.E. Reports of the work of this committee's investigators have been published from time to time, and have resulted in the Keenan steam tables, published by the A.S.M.E. But the research activity in steam has not been confined to this country. In England, Germany, and Czechoslovakia work has also been going on. Two international conferences of research workers have been held, and a third is planned.

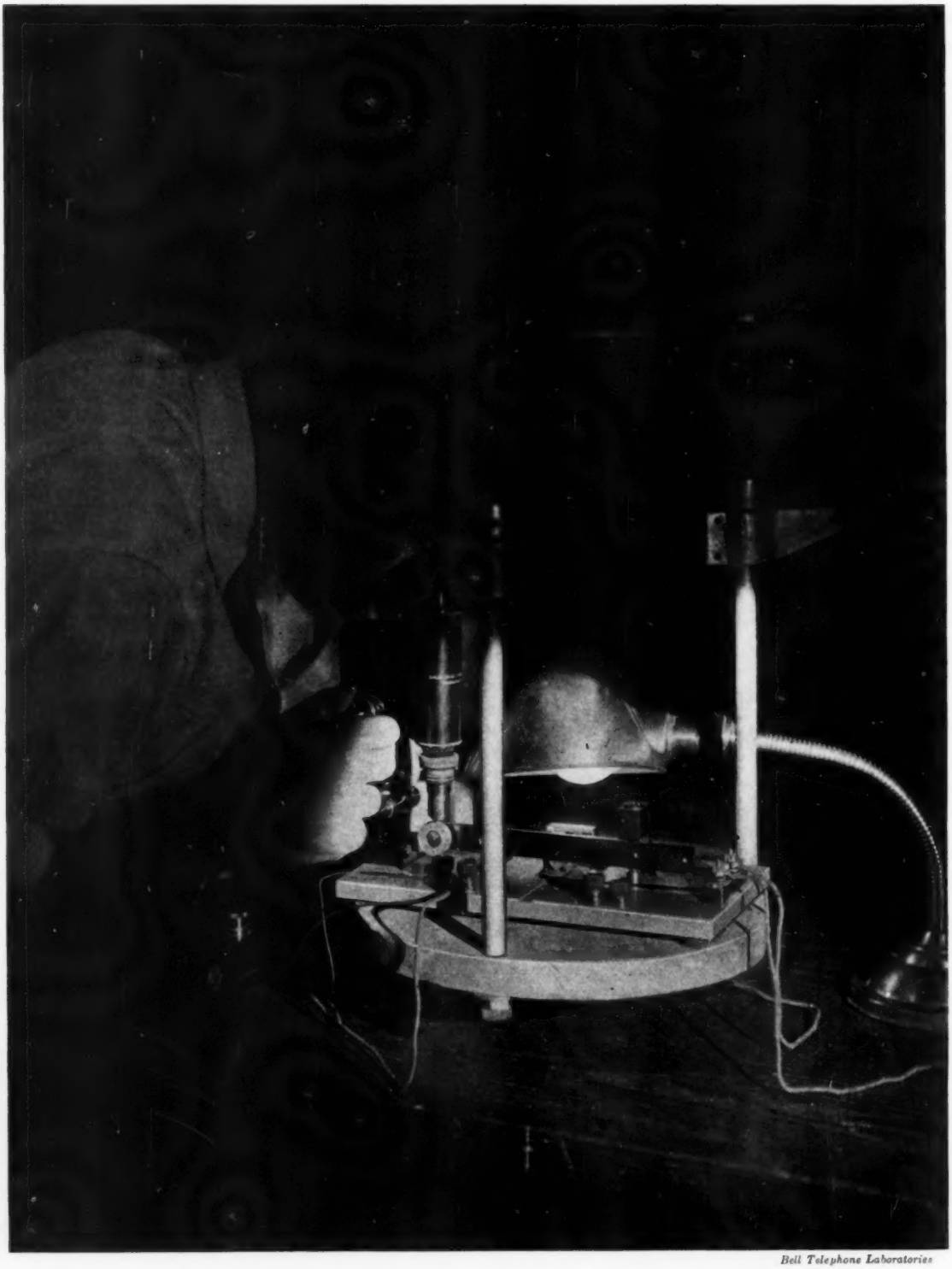
Last year Prof. Max Jakob, internationally known expert in steam research, delivered four lectures at the University of London in which he summarized recent investigations in Europe and the United States. The lectures were printed in *Engineering*, and have been abstracted for MECHANICAL ENGINEERING. The abstract is in two parts, the first appearing this month.

LAST month we printed the first of a series of articles on heat transmission that W. J. King, of the General Electric Company, has prepared for MECHANICAL ENGINEERING. This month's article deals with the phenomenon of conduction. Mr. King has assembled for practical use the basic laws and most authentic data pertaining to heat transmission by means of conduction in metals, alloys, heat-insulating materials, electrical insulating materials, miscellaneous solid and porous industrial materials, liquids, gases, and vapors. Engineers whose design work involves problems in heat transmission will find Mr. King's summary of the basic laws and data a valuable aid.

COMPETITORS of coal, one of which provides us this month with an illustration for our cover, were discussed at the Third International Conference on Bituminous Coal, held last November in Pittsburgh, Pa. Oil, natural gas, and water power are the serious contenders for the supremacy of coal.

From the papers at the Conference that dealt with these competitors of coal, liberal abstracts have been made to visualize the present status of the competition.

ABATING the smoke nuisance requires everlasting vigilance and persistence. Those who are responsible for the nuisance are not malicious. They are either indifferent, or ignorant of how to prevent the nuisance, or are faced with an excessive cost to accomplish worth-while results. Hence any device that can be installed without great expense and used with reasonable effectiveness in abating smoke, claims attention. In this month's issue of MECHANICAL ENGINEERING, A. C. Stern describes some experiments with a steam jet developed at the Case School of Applied Science, and recommended and used by the Smoke Departments of Cleveland, Ohio, and Hudson County, N. J. It is inexpensive and effective in creating over-fire air and turbulence in improperly designed hand-fired furnaces using bituminous coal.



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Research Provides the Basis for Modern Developments in Engineering and Industry

Problems Confronting The ENGINEERING PROFESSION

By FRANK B. JEWETT[1]

We have about us everywhere the evidences of attempts to control a new scheme of living through the rules and regulations which grew up in an essentially agricultural and trading age. We are witness to all sorts of legislative action taken in an endeavor to control by statute things which cannot be controlled except in the light of a complete understanding of their scientific and engineering significance. Under the circumstances in which we find ourselves, it seems to me that if the people of the world are to live happily in the years ahead, and if their affairs are to be ordered in measurably decent fashion, a better general understanding of the things of science and engineering is imperative. Nor can this better understanding be confined to the limited few who make up the group of scientists and engineers. It must be an understanding which in some measure enters into our collective thinking and into our acts as a group of human beings bound together by what we commonly call political ties. If this premise is correct it would appear that the engineer must of necessity play an increasingly important part in the general scheme of things, since he is the only man who in general has that full understanding of the facts of science as applied to the affairs of every-day life which is necessary for a proper operation of the new controls.

AFTER a great many years of activity in one branch of the engineering profession, and through it having had some considerable contact with practically all the other branches, it seems to me that we are approaching an era when the problems of the engineer, and particularly those of the engineering profession, are about to undergo some rather radical changes in their fundamental features. It seems clear not only that we are living in a highly mechanized age, but also that we and our children and their children are destined to continue to live in an even more highly mechanized environment. Periodically we hear or read statements to the effect that it would be nice if we could return to a simpler mode of living. Any such possibility seems to be quite out of the question, however. The things of science which have been made useful to the people through the work of engineers have not only come to stay but are destined to increase in number. They have come in such large measure already, and they bid fair to come in such greater measure in the years ahead, that many of the old controls which were developed through long ages of human activity no longer suffice for a proper ordering of them for the well-being of society.

OLD RULES FOR NEW CONDITIONS

We have about us everywhere the evidences of attempts to control a new scheme of living through the rules and regulations which grew up in an essentially agricultural and trading age. We are witness to all sorts of legislative action taken in an endeavor to control by statute things which cannot be controlled except in the light of a complete understanding of their scientific and engineering significance. Under the circumstances in which we find ourselves, it seems to me that if the people of the world are to live happily in the years ahead, and if their affairs are to be ordered in measurably decent fashion, a better general understanding of the things of science and engineering is imperative. Nor can this better understanding be confined to the limited few who make up the group of scientists and engineers. It must be an understanding which in some measure enters into our collective thinking and into our acts as a group of human beings bound together by what we commonly call political ties. If this premise is correct it would appear that the engineer must of necessity play an increasingly important part in the general scheme of things, since he is the only man who in general has that full understanding of the facts of science as applied to the affairs of every-day life which is necessary for a proper operation of the new controls.

PROBLEMS OF EDUCATION

It is true that individually, in practically every activity in which we engineers have engaged, we have had some influence in molding affairs. Nevertheless, acting as a group, we have not taken the same part in the evolution of society in this mechanized age that I think we are to and must take in the years ahead of us. If you grant this premise, then it seems to me obvious that there are two main problems—three, possibly—to which some thought must be given.

In the first place, there are the problems of education

[1] Vice-President, American Telephone and Telegraph Company, New York, N. Y.

Vice-Presidential Address before Section M (Engineering) at the Annual Meeting of the American Association for the Advancement of Science, New Orleans, La., December 30, 1931. Abridged.

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for the young men who are to be our engineering successors. Up to the present time our scheme of engineering education has been essentially one which acquainted young men with the fundamentals of their profession, something of the groundwork of science, on which all engineering is based, and in addition with the rules by which science is applied in the profession of engineering. Of course this aspect of engineering education is bound always to be a very large part in any scheme of technical training. There must always be a large number of men who are competent to take the facts of science and the rules of engineering and apply them for practical purposes. Further, no man is likely to achieve real eminence in the broader aspects of a social service based on engineering unless he himself is competent to do and judge at least some of the things which are the hallmark of good professional engineering.

Beyond this basic requirement, if I am right in my picture of the years ahead, it may well be that in some of our engineering schools more emphasis will come to be laid on the social side of the engineering profession. Where this is done the objective will be so to endow the young men who go out from the schools that they will be competent not only to do the kinds of things that you and I have been called upon to do in our active life, but more competent than we to take their places in the whole scheme of evolving society.

PROBLEMS PRESENTED BY TECHNICAL SOCIETIES

Then there are the problems which affect us in our professional association one with another, that is, in our technical societies. In the past our societies have been in large measure places of meeting where technicians could gather together for a general interchange of ideas, for a discussion of technical problems, and for the taking of whatever group action seemed advantageous for the advancement of our profession. Possibly in the years ahead we shall find it expedient and necessary to equip ourselves in better fashion to play the part which society has a right to demand of us, its experts in this particular field, in bringing to play on the problems which will confront our people the general consensus of understanding which we alone possess in the greatest measure.

Finally, there are the problems of a better education of the great rank and file of the population who have an interest in but no specific concern with the practical applications of science. I surmise that a large part of the things which we are prone to criticize in the acts of our political leaders, our political parties, and our various social groups, are not so much due to any malicious desire to warp the situation as they are to a fundamental ignorance of the factors which are involved. If I am right in this, then, to such an extent as is possible with a great mass of human beings, we owe it to ourselves and to the society of which we are a part, to do what we can to bring about a better general understanding of the possibilities and limitations imposed by nature. In a word, where the facts of science and their application are really the controlling factors in any proposed legislative and administrative undertaking, general knowledge of the inherent possibilities and limitations is highly advantageous.

NEED OF GENERAL PUBLIC FOR A BETTER UNDERSTANDING OF SCIENCE FUNDAMENTALS

All of us have had numerous illustrations indicative of the abysmal ignorance of men and women of intelligence about things which seem to us the every-day commonplaces of life. Nevertheless it seems to me that these millions of people must in the years ahead come to have a better understanding of the fundamentals of science and engineering than did their parents and grandparents. Moreover, we scientists and engineers must in some way or other take a real part in bringing about that education. Further, either individually or collectively we must be prepared to play a real part not alone in our purely technical activities, but as citizens of the community and of the nation in which we live.

There are two things which seem to me to indicate a change in the point of view and, through it, in the activities of engineers as regards the more strictly professional side of their work. One of these is that in many fields

of engineering we seem to be reaching the ultimate of possibility in our applications of the things of science.

Take, for example, the matter of dams. I presume that the first dams were built untold centuries before there was any recorded history. This being so, one might easily think that in all the long period of human history men would have had experience with every conceivable element entering into the construction of dams, and so would know all there was to be known about them. Yet when one talks with one's civil engineering friends, and when one reads the more or less acrimonious discussion which goes on with regard to the stability of gravity dams, the cause of failure of such structures as the St. Francis dam, and the probable stability of the great new Hoover dam, one begins to wonder just how much we really do know about them.

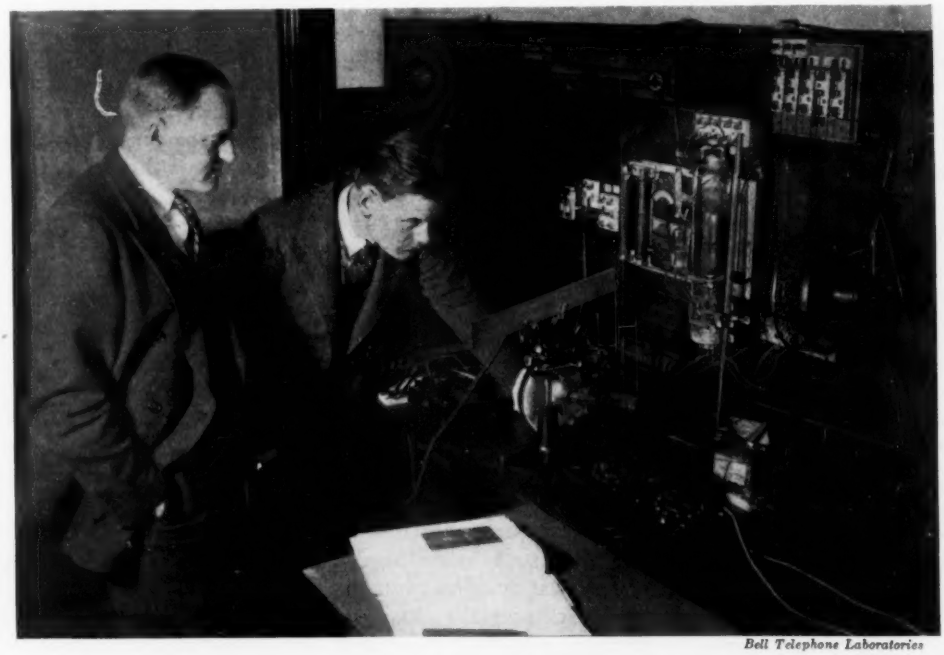
FIELDS OF ENGINEERING IN WHICH LIMITS OF POSSIBILITY ARE BEING APPROACHED

Despite such uncertainties, there are nevertheless some fields where there seem to be fairly clear indications that our present applications have reached close to the limit of the possibilities permitted to us by the fundamental facts of science.

As an example, I can cite one illustration in my own field of engineering where we seem close to the limit. Fifteen years or so ago very great advances were made in extending the range of electrical communication through the development and introduction of distortionless amplifying devices. As thus employed these devices are made to control relatively large amounts of fresh energy supplied to the transmission channel at points distant from the sending station, in such a way that the minute control impulses which reach them are magnified many fold without distortion of form.

These devices of practical utility, which grew out of fundamental research in physics, opened the door to what appeared to be an almost illimitable amplification of very small amounts of energy without distortion. Initially it appeared as though one might go on practically ad infinitum in the multiplication of energy under the control of very weak impulses, and so provide for spanning almost any terrestrial distance which might be involved in electrical communication. Recently, however, in our attempts to span great ocean distances, such as the Atlantic, with a telephone cable, we have come face to face with what appears to be the stone wall of a fundamental obstacle inherent in the nature of matter. Here, because we are deprived of the possibility of installing intermediate amplifiers, we must, if the problem is to be solved at all, depend, at the distant end of our circuit, on the minute portion which remains of the energy imparted to that circuit at the sending end. However, we find that the remnant of energy with which we have to deal is so minute that it is approaching the level of the electrical energies involved in the noises produced by thermal agitation within the material of the conductor itself. A short step further in this diminution, such as might easily be produced by an extension of distance, will bring us to the point where no amount of amplification can be of service, since any amplification will elevate equally both the desired impulses and their masking background of noise—and we know of no way of separating the two.

Other examples might be cited to indicate that in certain other branches of engineering there are, in the present state of our knowledge, definite limits to what we can do in an engineering way. Where such fundamental obstacles are found to exist, it is obvious that the past course of engineering development, on its more technical side, must be altered. In a word, we shall have in such fields reached the frontiers, and must consequently direct our energies to developments within those frontiers. Put another way, it means that in those particular sectors the engineering of the future must be directed to the problem of filling in gaps which now remain, in bettering the structures which we have already erected inside the frontier, in cheapening



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ACCURATE MEASUREMENT AND CORRECTLY INTERPRETED OBSERVATIONS ARE FUNDAMENTAL TO RESEARCH

these structures, or in the thousand and one ways with which we settle up an already discovered country.

In other directions and in other branches of engineering it is quite obvious that we have not yet reached the point where such limits have begun to operate. In these fields progress can still be made along the old lines, although even in such areas I imagine that, relatively, we shall see much more attention given to the filling-in processes as we go along than may have been the case in times past.

NEW METHODS OF APPROACH IN THE YEARS AHEAD

There is another direction in which it seems to me that the engineering profession of the years ahead is likely to have a somewhat different point of view and a somewhat different method of approach from that which we have known in the past. Fundamental science has been bringing to us as raw material for our profession, these last three or four decades, a perfectly stupendous amount of new knowledge. New facts thoroughly proven in the research laboratory have been placed at our disposal to be applied as were the older facts which were their predecessors. In the main these new facts have had to do primarily with the ultimate structure of matter.

Further, in many branches of engineering this added knowledge which the physicists and chemists are placing at our disposal is indicating quite clearly the basic causes of some of those failures which in the past we have guarded against by the rather crude processes of enlarged dimensions which we have come to designate as factors of safety. Factors of safety will still be involved to insure against the unknown in the matter of maximum stresses, but they should in large measure be eliminated in so far as the inherent properties of the structural material itself are concerned.

Obviously, the more we can know with certainty about the things with which we deal, the farther we can go in refining our engineering in the design of our structures. This fact alone seems to be certain to have a very considerable influence on the type of education which we shall afford the young men who are to be the engineers of the future. Those among these young men who have in them the ability to reach the top of their profession, must be provided with a better knowledge of physics and chemistry and the underlying principles which guide their practical application than you and I were given when we were going through the rudiments of our technical education.

NECESSITY FOR A MORE INTIMATE KNOWLEDGE OF BASIC THINGS

As an illustration of the necessity for this more intimate knowledge of basic things, it is easy to show in some branches of engineering that such knowledge is absolutely essential to progress and safety. For example, we have in recent years learned that in certain alloys and aggregates very minute admixtures of certain substances produce effects which are out of all proportion to the amount of the extraneous material. Frequently these effects have been deleterious, and the minute admixtures have been referred to as poisons. In other cases the effects have been beneficial.

This discovery was a striking illustration not only of the effect of small things in upsetting the calculations which might otherwise have been made, but also of the dangers which one runs in proceeding too boldly to use some new discovery without making the most complete an exhaustive investigation of the things which may result from slight deviations from absolute perfection.

Thus in many directions the engineer of the future, in my judgment, must of necessity have a much more certain and more intimate knowledge of the materials with which he works than has been the case in the past. As a result of this more intimate knowledge his structures will be more refined and his factors of safety in many directions are bound to be less because the old elements of uncertainty will have in large measure disappeared. All in all he will be working on a sounder base of knowledge than has heretofore been possible. To the extent that this is possible, it must inevitably have a very considerable influence on the type of education given in our technical schools, at least to the men who have the inherent capacity to develop into the leaders of the engineering profession.

STIMULATION EXPERIENCED IN THE CREATION OF PHYSICAL THINGS

Whatever changes there may be in the intellectual or social phases of engineering, one cannot escape a realization of the tremendous interest which resides in the purely physical. It is a form of interest which does not exist in any purely intellectual type of achievement. As one advances in years and experience, the normal tendency of the engineer is to become more and more involved in phases of engineering which are essentially intellectual, and to a large extent lacking in personal contact with the purely physical. No matter how much satisfaction one may derive from the successful completion of a task of this kind, it is devoid of much of the thrill that accompanies the creation of a physical thing with one's own hands or through one's own efforts. As a matter of fact, I doubt if I derive as much personal enjoyment from the things of my business life as I do from the simple little structures which I make in my own shop merely as a matter of personal relaxation.

There is something stimulating in the creation of things which exist physically, which you can look at or feel, which does not exist in any purely intellectual achievement. This being so, I would not for a moment desire that the training of engineers for the future should so overemphasize the purely intellectual side of our profession as to blot out the training which will enable men to produce things physically.

We must always have in mind that our engineers, in the last analysis, must be the creators of physical things if they are to be real producers, have a real understanding of their profession, and be able to play the enlarged part which I foresee to be the province of our successors.

RESEARCH *for* INDUSTRIAL PIONEERING

By JOHN P. FERRIS[1]

UNTIL about twenty-five years ago the world looked to individual inventors to point out new paths for technical progress. The inventors had to conquer the intervening difficulties, for the most part single handed, and had to demonstrate operative mechanisms or processes in order to enlist support and get powerful organizations behind their ideas. A large part of our engineering progress has come about in this way—Stephenson's locomotive, Faraday's dynamo, Parsons' steam turbine, Edison's electric light, the Wright airplane, Marconi's wireless. The magnificence of these conceptions carried them far, but the time came when limitations of knowledge slowed up their progress. It is only quite recently that the technical arts admitted that they had to turn to organized research for the data on which to proceed. It took patient work in the laboratories to unleash the miracles of high-tension electric power transmission, to make possible the 200,000-hp steam turbine, long-distance telephony, the transatlantic airplane and airship, and other outgrowths of the inventors' original ideas. The ability of research to remove limitations was powerfully demonstrated, so that most great industrial organizations became research-minded and organized research laboratories. To these laboratories they turned over problems for analysis and solution. At first, the problems attacked were those which could not be answered by reference to past experience or classical theory. But they were generally what the inventor-designers felt to be problems of detail—matters which, though annoying, were not of the essence of the designs which gave rise to them. The laboratories solved these problems, and in the course of their work they began to compile data not included in former knowledge, and frequently contradictory to it. Their conclusions often superseded current ideas, and forced their acceptance by the weight of facts. Laboratories acquired new prestige from these victories.

RESEARCH THE MOST FERTILE SOURCE OF NEW IDEAS

Now research has gone a step farther and is on the center of the stage. It has become the most fertile source of new ideas. The day of the individual inventor is passing; we are rapidly approaching or have arrived at the point where basic technical advances come as an outgrowth of painstaking analytical and experimental work, largely in the laboratories. Where once we looked to them only for tests confirming what we already knew or for help in locating and eliminating minor limitations in our technical products and processes, we now admit that they are more likely than we to open up great, new fields of progress.

Many of the industrial products which occupy the center of the stage now were recently born in laboratories; they were not the children of inventors' minds in the same sense as were the electric light and the steam hammer. Consider this list: Cellophane, Bakelite, rayon, corrosion-resisting steels, the 325-mph racing seaplane, the 50,000-ton, 30-knot ocean liner, anti-knock gasoline, irradiated foods, sound pictures, television, and the new strong alloys of aluminum.

We are entering a new phase of the industrial age, in which our achievements will rest largely on the successful coordination of the efforts of individuals into group patterns such as the Bell laboratories, the General Motors research laboratories, the General Electric and Westinghouse research departments, the Dupont laboratories, the medical-foundation laboratories, and last, but not least, the university laboratories.

From now on, sound technical progress will follow research. There will unquestionably appear more great inventors of the stature of a Diesel or a Sperry, but the results of extensive research will be the raw materials upon which their inventive work will be exercised.

We can all agree that industrial development should follow lines which will improve the efficiency of the industrial machine as a servant of mankind. I refer to the industrial machine, and not to the economic machine, which is another matter. The latter is not working well right now. In fact, it is working so badly that most people are beginning to question its fundamental engineering—to doubt whether its basic pattern is well adapted to its function as a foundation upon which all activities in a highly organized community must rest. Distrust of the economic structure leads many to point accusing fingers at the scientist and the engineer as the authors of our woes. But in so far as we have put our efforts to increasing by invention and discovery the possibilities for the production of desired goods and services, we have worked only to put into the hands of mankind tools for his liberation from the age-old slavery to the earth. If we have made it possible to grow more food with less land and labor, millions should have more leisure for other

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Address delivered at a joint meeting of the Engineers' Society of Milwaukee and the Faculty of the College of Engineering, University of Wisconsin, Madison, Wis., June 22, 1931. Reprinted, slightly abridged, from the October, 1931, issue of *Milwaukee Engineering*.

things. If we have found ways of producing clothing in greater abundance, we should be thanked for the greater comfort we have made possible. The high per capita production of goods which has been achieved should mean more goods and more leisure than ever before, not destitution and fear for the future. If in the face of potential plenty some 40,000,000 people in this country and in Europe are in serious want of necessities, the accusing fingers should be pointed, not at the technical sciences and engineering, but at the economic structure, which should be based on science and is not. Our present economic misfortune shows the need for more science, not less, in our lives. And if our scientists and engineers are moved by it to turn their minds to a study of the economic foundation which has so signally failed to endure the loads it must carry under our modern conditions of life, I, for one, consider that the tragedy will have been worth what it cost.

TESTING THE EFFECTS OF LIGHTNING ON AN AIRPLANE BY MEANS OF A MODEL AT THE HIGH-VOLTAGE LABORATORY OF THE OHIO INSULATOR COMPANY, BARBERTON, OHIO

Engineering research, in leading the way for industrial development, should be consciously directed to the improvement of the efficiency of the industrial machine as an agency of social development. The selection of the subjects for research is a vital matter in achieving this ambitious result. The position of the universities is such that their policies in the direction of their research work have a considerable influence on the course of technical progress, and can have a much greater one.

SELECTION OF SUBJECTS FOR ENGINEERING RESEARCH A VITAL MATTER

In the past, university research in engineering has concerned itself to a large extent with problems which have become prominent in established industries. A problem was adjudged important and worthy of research effort if its solution would be of immediate use in industry. This was a practical stand to take, and yet its implications open it to question. For one thing, it meant that, by and large, most pioneer research work for industry was initiated by the industries for their own ends. They broke the ground, and the technical schools followed. Examples of this tendency are numerous. Those which come to my mind are the many investigations of the fatigue of metals in the universities which have followed similar work in the industries; automotive-fuel tests; locomotive performance; the art of cutting metals. It has seemed that each new industry had to wait until it showed a high dollar-earning power before its problems were adjudged worthy of research effort by the universities. Most of such problems would be solved within a short time by the industries concerned in any case, and in applying their energies to them the universities exert no broadly guiding influence on industrial development.

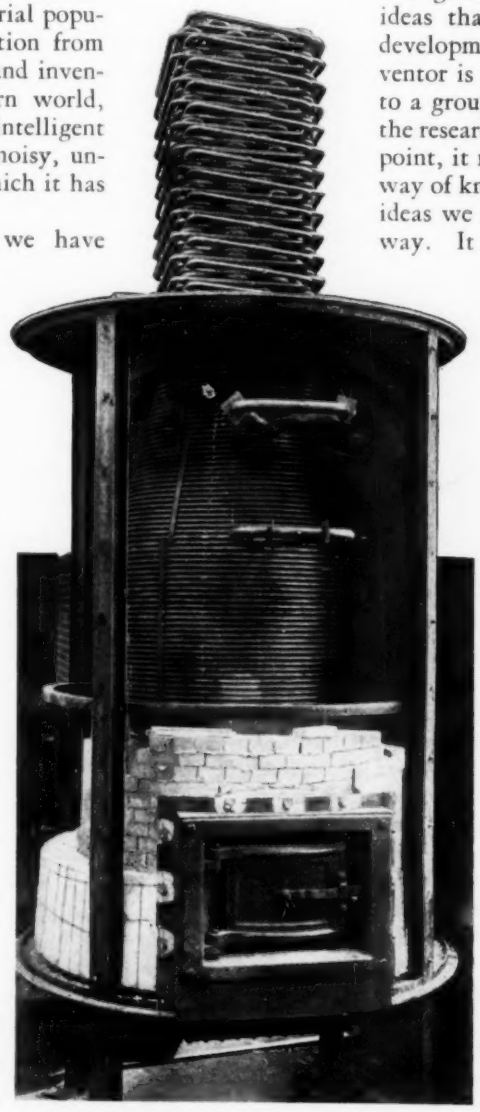
The common assumption is that business applies itself to invention and the development of a solution for each industrial need automatically when the time is ripe, and this assumption is probably responsible for the tendency of university research to follow the trends of industry. If a given industrial job isn't done at all, according to this philosophy, we must wait for some one to combine the inspiration, the certainty of being able to carry the necessary research work to a successful conclusion, and the ability to raise money to pay for the research work, as well as the building up of a commercial organization. No one can question the impressiveness of the mechanical developments which have been brought into existence by business in response to the profit motive. These developments have transformed our world in a few generations.

OUR MACHINE AGE A HODGE-PODGE OF DESIRABLE AND UNDESIRABLE ACTIVITIES

And yet our machine age is a hodge-podge of desirable and undesirable activities side by side. Things are made which can lighten labor and broaden men's lives, such as electric power and automobiles. At the same time we build new skyscrapers in communities where

the traffic problem was already insoluble; we squander raw materials and human effort recklessly in making countless silly little knick-knacks that no one really wants; we crowd ourselves into pigeon-hole apartments in which children cannot possibly be brought up with a wholesome outlook on life; we burden our lives with noise, dirt, nervous pressure, and overcrowding that prevent most of our industrial population from deriving real satisfaction from their daily work. Yes, science and invention have transformed the western world, but there are few sensitive and intelligent people who are satisfied with the noisy, undirected, restless maelstrom into which it has been transformed.

We must demand more than we have gotten from the machine age. Recovery from the present breakdown will be in itself unfortunate if it does not leave impressed on our minds forever the urgent need of guiding the industrial machine toward desired ends far more than has ever been done. It is often said that what we need now is new industries to make something which people will want badly and will buy. Most of these remarks assume that it makes little difference what the new thing is, so long as people can be made to want it. I think our attitude should be very cautious and critical with respect to this idea. We do want new industries provided they can make something which we need and the presence of which will make life more livable and enjoyable. We do not want them (except perhaps as a palliative) if they are to make useless baubles not worth having, slug people by modern psychological art into wanting them, and then drive them at a mad pace to produce too many of them.



HIGH-PRESSURE STEAM BOILER (OUTER COVERING REMOVED) USED IN RESEARCH WORK AT PURDUE UNIVERSITY

The universities can exercise a strong influence in directing future industrial activities toward desirable ends. At every step they should attempt to lay foundations for the intelligent planning of industrial activities. It is in my mind certain that we shall soon be forced to create some sort of Economic General Staff for the entire country, such as Mr. Stuart Chase suggested in *Harper's Magazine* of June, 1931. One of its major tasks will be to attempt to steer capital into new industries which will get us somewhere, socially speaking. Such a directorate will have to be guided as to technical possibilities by impartial research, research which has no axe to grind. The 150 or so research laboratories in the universities should be looked to for many of the data to guide them.

But quite irrespective of any future Economic General Staff, we are faced now with the need of bringing out and getting into circulation new industrial ideas that lie buried. At present no new developments are completed unless the inventor is able to paint a commercial picture to a group of financiers. If he can't finance the research required to bring his idea to this point, it must languish untried. We have no way of knowing how many thousands of the ideas we need are stopped right now in this way. It is quite possible that half a dozen different men have in their minds ideas which, if followed up energetically, would lead to the discovery of new sources of cheap power to replace coal and oil when they are gone. Claudel and his sea-water heat engine are well backed; perhaps men who could show us cheaper and more practical sources are not. Who knows? If there are such men they may well have failed to raise money on the strength of their ideas. It should be a policy of university research to follow up important possibilities of this sort.

Along with our failure to apply our impartial research facilities in the universities to many of the more important known industrial needs, is the failure to eliminate excessive and unknown duplication of effort in research laboratories operated by competing businesses. As long as our patent laws are as they are, there is little that can be done about this. It is quite certain that General Electric and Westinghouse research engineers are working furiously and independently on the same problems, each group without the benefit of the assistance which the other could furnish. The same situation holds good throughout all industry. Whether the benefit of the spur to activity which competition furnishes is greater than the obvious losses due to duplication of effort, is an open question. With respect to the work of engineers and scientists, I very much doubt it. I think that more would be accomplished at the end of a year if these men were working on different problems. We might compromise and suggest that two or three independent

groups work on the same problem, thus preserving the principle of the competitive spur to achievement; now we frequently have not two or three, but a dozen groups working on the same problem.

HOW UNIVERSITY LABORATORIES CAN BE MOST EFFECTIVE IN GUIDING INDUSTRIAL DEVELOPMENT

Our university and other non-commercial laboratories can be most effective in guiding industrial development by adhering to three principles:

1 Each research project undertaken should be something that would not be done at all or not as well if left to a private agency. In this way more new ground will be covered; the universities will gradually assume a position of leadership in research.

2 They should attempt to minimize duplication of effort in research. The very fact that a university laboratory undertakes a project will deter individuals from undertaking projects along similar lines without first finding out what research work is already being done. It may be desirable for two agencies to work on the same problem, but each of them should at least know of the existence of the other's efforts. In other words, duplication should exist only to a known extent, not to an unknown extent.

3 The objective of each project should contribute to something which is socially desirable—something which needs to be done.

A question which arises immediately is this: How shall we know which new things should be done until the inventor has shown us? Thirty years ago we did have to wait for an inventor to show us what we wanted and how to get it. Today this difficulty is disappearing, not because any less remains to be done, but because we are becoming familiar with the actual working of a highly industrialized and mechanized society. We have lived in it and feel its comforts and its discomforts. It is comparatively easy for us now to see that some of our important needs are those given below. No one is likely to undertake as a research project the complete achievement of any one of them. But it is not unreasonable to suggest that non-commercial research projects be checked against some such general scheme of objectives.

IMPORTANT PROBLEMS AWAITING RESEARCH

We need a better and cheaper house for the average man, probably one that can be made in a factory to take advantage of factory economies. It must be sold at about one-third or less of present prices for houses of equal size, and embody the beauty that results almost inevitably from skill in design and the use of materials.

We need new patterns of community arrangement to bring farmers closer together and spread urban workers farther apart, to break up the nerve-wracking congestion of metropolitan cities. We need city engineering, both for structures and traffic control.

We need highway designs to increase the safety and pleasure of driving.

We need new fuels and sources of power. The Savonius wind rotor is an example. Perhaps we must find it in some unstable atom; perhaps in the tides or in the center of the earth or in cosmic rays.

We need safer flying, in which the craft is inherently so stable and so easily maneuverable that the pilot need not possess extraordinary skill. Minor mechanical failures during travel, such as those encountered in automobiles, should not result in accidents.

We need foods which can be prepared with less labor—possibly synthetic foods. We need better methods of agriculture that will produce very much more on less land, so that farmers need not live so far removed from each other and from the centers of culture and amusement. We need food so cheap and easy to obtain that it will take its place beside air and water as necessaries of life that are almost free, available to all, and thus removed from the list of things for which men must strive. The effects of such a change in our attitude toward food and shelter would revolutionize life and would eliminate much of the drive behind economic strife, warfare, and cruelties of all kinds. It would leave us freer to strive after real pleasures and real accomplishments.

We need any number of new materials, such as ductile and workable glass, synthetic leather (to make unnecessary the slaughter of animals which will soon be no longer needed for food), synthetic rubber, cheaper materials for clothing, etc.

We need ready access for all to recreation areas for recuperation from the nervous grind of industry.

We need more efficient heat engines to conserve our fuel supplies.

We need to develop ways of using wood to better advantage, reforestation, and a technique of harvesting lumber as a crop, that our forests may be restored. This is required to insure our lumber supply and also to preserve the forests for recreation.

The entire question of noise must be investigated, together with its bearing on machine design, so that machinery can be built to operate silently. Most mechanisms now in existence should eventually be scrapped and replaced with new ones which are silent.

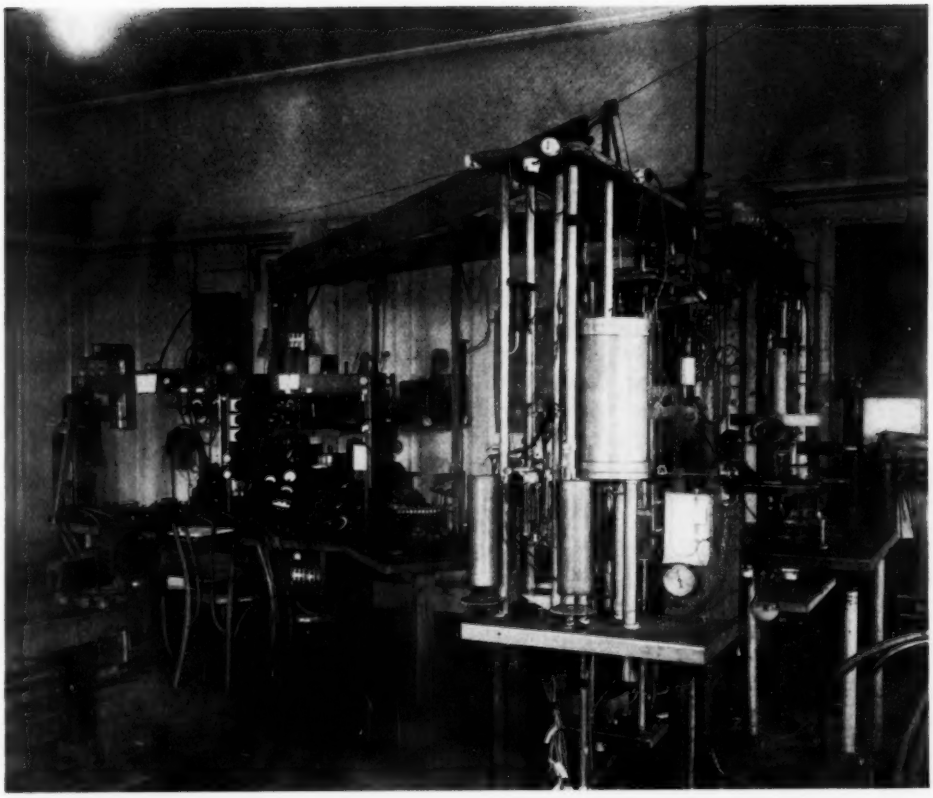
We need further development of flexible power-transmission devices, to be used in connection with prime movers which operate characteristically at constant speed, such as Diesel engines and alternating-current electric motors. This problem is felt in excavating machinery, locomotives, trucks and buses, manufacturing machinery, automobiles, and many other fields.

Aside from the physical problems such as those mentioned above, there is an entire class of non-physical problems which are now more vital to human welfare than the physical, and they have been more neglected.

For instance, engineering must work hand in hand with economics and psychology in order to develop a technique of introducing new machinery and new processes into use in such a way that their benefits will be ob-

tained without the counterbalancing economic disorders which now bring with them suffering and fear. In the past the engineer has been satisfied when he has increased production or devised something new and desirable; in the future he must also devise methods of bringing them into use in such a way that no one suffers as a consequence.

Another field in this class is that of management. It would be desirable to discover a technique which will preserve the merits of the present absolute authority of management as far as technical efficiency goes, and yet modify the absolutism in order to allow a far greater amount of self-expression for the individual worker. There is ample evidence that much is to be gained in industrial efficiency along these lines. The compelling reason, however, for such a change in human relations is to restore to the industrial worker the sense that he is a person, and is expressing himself in his work.



APPARATUS IN USE AT BUREAU OF STANDARDS, WASHINGTON, D. C., FOR MEASURING HEAT CONTENT OF WATER AND STEAM UP TO 600 F AND 2,400 LB PER SQ IN.

Today these questions do not seem so far removed from reality to most of us as they did a few years ago. We are face to face with the absolute necessity of solving them if our industrial order is to endure. Their solutions probably offer no more serious obstacles to our resources today than our present material achievements presented to our fathers.

Most of these problems are concerned with increasing the general material well-being. To quote Mr. Ralph Flanders, ". . . We are carrying water in a sieve if we attempt in any . . . effective way to bring goodness, truth, and beauty appropriate to our age into the common life without correcting our material ailments. Satisfactory physical conditions are our first responsibility, and the prime essential of any lasting success."

COORDINATION OF RESEARCH EFFORTS NEEDED

Any such program implies some agency for coordination of efforts. The need for coordination is so obvious that it will appeal to the common-sense of the university authorities, to the engineers' societies, and to government laboratories.

Much has been accomplished in the intelligent direction of research by the Engineering Foundation, acting for the engineering societies. It has made a considerable start in cooperating with the university laboratories in research work. It has appropriated funds and assisted in various ways to insure that the work done should be effective and that duplication should be avoided. One of the difficult problems in coordinating research is to discover a way of getting full cooperation from industrial concerns. Our patent laws necessitate very secretive policies, which fact is partially responsible for the preponderance of university research work on nonpatentable ideas. This constitutes a serious obstacle to the development of the full usefulness of research, and a strong reason for attempting to overcome the obstacle.

It would seem practicable for each university engineering laboratory, the Bureau of Standards, and other governmental organizations to agree with the Engineering Foundation on an outline program, and to direct most of its work toward the achievement of that program. Such a procedure should gradually develop a method of deciding upon and assigning research work to the laboratories best qualified for each task, of analyzing the results, piecing them together with other knowledge, and making them available in form for use.

It will be the task of the business order to convert the facts and knowledge found into tangible advances in human welfare. It will probably be necessary for business to call rather extensively on engineers and to adopt some of their viewpoint in order to do this.

ENGINEERING, *Investment*, *and* SOCIAL WELL-BEING

By RALPH E. FLANDERS[1]

THE responsibility of the engineer for the present social order is generally admitted. The profession is offered this responsibility as a badge of honor or of doubtful accomplishment, depending on the state of society and the state of mind of the observer at the moment. As for ourselves, we have never been willing to take full credit or blame for the way in which our structures, mechanisms, products, and processes have been used. That responsibility we share with the whole body of our fellow-citizens.

There is now appearing, however, a clearer understanding of our special services and responsibilities which will put us in a new relationship—one which we cannot and should not wish to avoid. This new relationship is, superficially at least, a complex one. Only two of its aspects will be noted here.

Within the last fifty years there has been in process of accomplishment that union of engineering and business which we Americans call "scientific management," and which our European friends have named "rationalization." One of the broad aspects of scientific management, recently developed, has been the practice of "long-time budgeting." This useful policy applies to the activities and expenditures of a business, a program of control which is based, not on immediate needs nor even on the fiscal year, but on the full period of the business cycle. In its practical application as an engineering and business principle it is new since the depression of 1920 and 1921. It has been applied with varying degrees of thoroughness and success by hundreds of the larger businesses of the country during the present unpleasantness. If it had not been so applied it is safe to say that disastrous shipwrecks would have overtaken a large number of firms which are now safely riding out the storm. The blundering expedients of 1920 would never have served for 1930–1932.

NEED FOR LONG-TIME BUDGETING POLICY IN GOVERNMENTAL FIELD

The new area to which engineering control must be extended is in the governmental field. Here there is clamorous need for a long-time budgeting policy. At one moment governmental bodies and their constituencies are fired with the possibilities of extensive public works as a measure of control and constructive relief. A few weeks later a new wave of emotion sweeps the country, and every possible expenditure is reduced or eliminated. Sometimes we are obsessed with both ideas, and try to persuade ourselves that we are extending public construction and cutting our budgets to the bone at one and the same time.

Such emotional instability of purpose must in some way be replaced by a more consistent and foreseeing policy, as has been done in the better-managed private businesses. During the course of the business cycle there is a time to borrow and a time to repay. There is a time to expand construction and a time to contract it. There is a time to tax and a time to relieve the burden of taxation. The problem is more difficult of solution than in private business, but it can and must be solved. The naive policy of balancing the budget within each individual fiscal year involves such elements of general economic unbalance that we cannot extend to it our continued acceptance and approval.

The other economic aspect of engineering which will be mentioned relates to its function in finding profitable investment for savings. In this matter we are dealing with the heart of the problem of the business cycle.

We may blame the climactic disaster which ends a business boom either on "overproduction" or "underconsumption" as we please. Both phrases in the end mean the same thing—that the population as a whole is unable to buy back the goods it has made. In 1929 there may have been—there were, in fact—some classes of goods of which more were made than the people as a whole had any desire or need for; but this was not true of goods as a whole. At the height of production the mass of unsatisfied desires on the part of people who were able and willing to work effectively was beyond calculation. What prevented that willingness to work from receiving the goods to fill the unsatisfied desires? The answer is not too difficult for human comprehension.

THE QUESTION OF PURCHASING POWER

A classical economic theory asserts that purchasing power normally keeps in balance with production, being in its nature complementary thereto and consequent upon it. Under an ideal condition where business enterprise is neither expanding nor contracting, but is regularly paying out all it receives—and under which condition all individuals, governments, and the like do the same thing—the theory holds. In this ideal state a manufacturing firm making and selling $100,000 worth of goods per month would pay out the same total amount per month for materials, wages, salaries, services, interest, dividends, taxes, maintenance, replacement of worn equipment, and the like; and every individual and organization to which a payment was

[1] Springfield, Vt.

made would likewise disburse the sum received. Thus the entire $100,000 remains in the general pool of purchasing power. Under these circumstances goods produced are purchased by the earnings of the processes of production.

But this is not the normal course of business, for both individuals and business enterprises find it necessary to lay by funds for future use. This act of saving, for a time at least, withdraws funds from purchasing power and thus makes it impossible for society as a whole to buy all the goods produced. Savings are necessary, however, although they tend on the whole to prevent the purchase of all the goods produced. This is the celebrated "paradox of thrift."

Further study shows that the normal way in which savings are returned to purchasing power is through the act of investment. By investment is meant *new* investment. What most distinctly is not meant is that *A* should buy old stock certificates of *B*, in which case the stock shifts from *B* to *A* and the money from *A* to *B*. Under this condition the problem of getting this money to buy goods still remains. If on the other hand the savings or moneys are used in investments in new buildings, factories, homes, utilities, and other new wealth-producing activities, actual purchases are made, and hence a tendency to maintain a balance between production and purchasing power is established.

Nature of the Typical Business Cycle

As an example, it is probable that the general purchasing power of the country was maintained during the comparatively prosperous years from 1922 to 1926 by the rapid flow of millions of dollars of savings into the expanding automobile and other industries. Savings were not held out of purchasing power to any appreciable extent during that period, and thus purchasing power kept step with production.

There is one important reason why from time to time the rate of saving exceeds the rate of investment, thus initiating a decline in business. When too small an amount of the disbursement of wealth goes to those who earn wages and small salaries and too large an amount is paid those who earn large salaries and receive dividends, there are likely to accrue savings which cannot be profitably invested. The reason for this is that money paid to wage earners and low-salaried employees is usually spent. Their needs are so insistent that only a small amount can be saved. Therefore any increase in disbursements to these classes is likely to broaden the market for goods. If, instead, largely increased payments are made to those who normally spend little and save much, it may well be that, with no corresponding broadening of the wage earners' purchases, these savings will find no profitable investment and will thus be lost to purchasing power, and hence a business decline is initiated. Uninvested savings—of which there are hundreds of millions idle or "liquid" in the banks of this country and hoarded in deposit boxes—are equivalent to unbought or at least unpaid-for goods. There is, of course, no perfect equality, for the money side is an elastic quantity, and goods deteriorate, become outmoded, or are discarded for other reasons.

In the meantime, at the peak of the boom, the distribution of profits not destined to be supported by actual increased purchasing power gives an illusion of permanent prosperity. As a consequence, stocks rise, money is lost to purchasing power through flowing into the stock market in preference to seeking lower returns from investment, and an uncontrolled and inevitably disastrous boom is on.

Such appears to be, in its simplest terms, the nature of the typical business cycle, which is in part responsible for the current economic distress.

The other elements in our present condition—the post-war deflation, the breakdown of international trade and credit, etc.—are important, but do not overshadow the influences just described.

When Saving Becomes a Menace

We may sum up by saying that the total returns from industry, as from our hypothetical manufacturing establishment, must either be spent or saved. Spending may be done to any amount which does not prevent the maintenance and regular replacement of the means of production. Within these limits spending cannot be so great as to disarrange the industrial mechanism; although of course from an ethical or esthetic standpoint the spending may be done for the wrong objects by the wrong people.

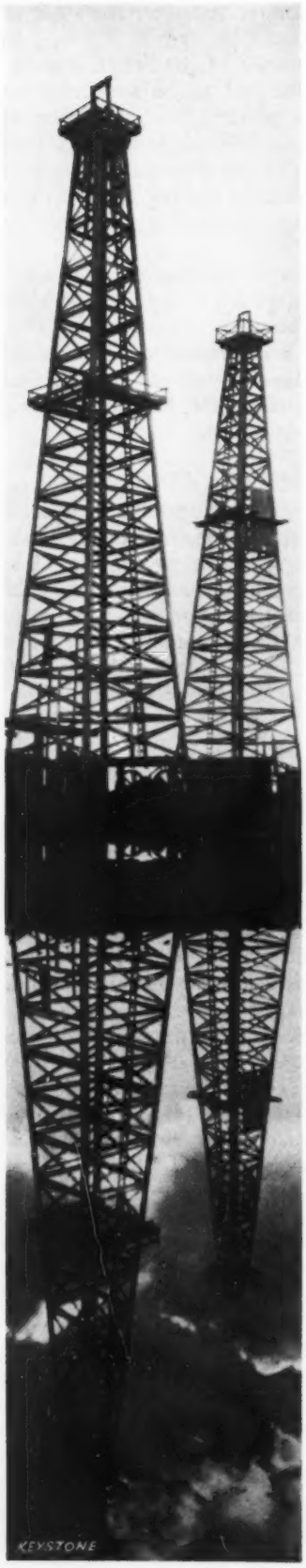
Saving, on the other hand, must be and normally is great enough to provide for the replacement of obsolete equipment and processes, and to provide for expanding populations and expanding needs. In other words, saving must be sufficient for profitable investment or hopeful development, both of which involve actual purchase of goods and payment of wages. But if saving exceeds the amount which can be devoted to these profitable and hopeful ends, and thus cannot be or is not spent for goods and wages, *then* saving becomes an effective menace to the orderly flow of goods from producer to consumer.

As stated before, this excess of savings and their diversion into sterile activities did take place in 1928 and 1929. The savings of many ordinary men, but above all of large and small businesses and of their stockholders and officials, were diverted into margins and into the money market for the support of speculation, into the financing and unloading of investment trusts and pyramidal holding companies, and into numerous other falsely attractive projects, every one of which involved in its own degree a definite inability of consumers to purchase goods then on the shelves or being produced. And this fact was the insecure foundation which finally gave way and toppled the whole ridiculous structure.

Remedies for the Situation

Many of the remedies for such a situation are obvious—and obviously difficult of application. Strange to say, courageous spending by people of means appears to be

(*Continued on page 296*)



COAL AND ITS

The Contest for Energy-Generating Oil, Natural Gas,

THERE was a day when commercial power generation on a large scale meant the burning of coal. Some power was generated from water, but its amount was comparatively negligible and its application purely local. Natural gas was probably the first considerable competitor of coal. This was followed by use of blast-furnace gas, which was, however, strictly local, and then by gasoline and oil. Recently the situation became so serious that a number of papers were devoted to it at the Third International Conference on Bituminous Coal, held last November in Pittsburgh, Pa.[1] Today, according to A. G. White, who presented one of these papers, the primary competitors of coal are: The group of oil products including fuel oil, gasoline, and kerosene; natural gas, except the amounts used in the production of carbon black; and the energy developed from water power. The increase in the volume of energy derived from these sources must not, however, be taken as a measure of the total net increase in world energy consumption. A considerable part of the use of these modern forms of energy represents a substitution for older forms. The steamship has now almost entirely displaced the old sailing ship dependent on wind power. The automobile and the tractor are replacing the horse and other farm work animals. Coal, oil, gas, and electricity have superseded wood and charcoal as domestic fuel in advanced and densely populated communities. Factory machinery has been substituted generally for human labor. Thus a considerable part of the modern increase in energy consumption must be regarded as a shift from older to newer sources. When due allowance has been made, however, for this factor of substitution, there still remains a large net increase in the total consumption of energy, derived largely from mineral fuels and water power.

In 1909 coal furnished almost 89 per cent of the modern forms of energy. By 1929, however, the total amount of energy generated had increased by the equivalent of nearly 800,000,000 short tons, while the proportion of coal had decreased to 74 per cent. Coal and its competitors shared about equally in the increase. The slow increase in the world demand for coal must be considered in the light of two primary factors of about equal importance: namely, the competing sources of energy measured on a coal-equivalent basis, and improved fuel efficiency.

In the course of his paper Mr. White discusses competitive conditions in the six major coal markets of the world, as well as the relative position of coal in these markets in relation to total energy consumption. He comes to the conclusion that the serious problems arising in the world coal industry are largely centered in Northern Europe and the United States

There was a gain in total world coal consumption of approximately 155,000,000 short tons of coal, reduced to bituminous equivalent, in the maximum year of 1929 as compared with 1913. In Northern America the increase was only 45,000,000 tons—42,000,000 for the United States and 3,000,000 for Canada. Northern Europe showed a gain of 51,000,000 tons, made up of a loss of 17,000,000 for the United Kingdom and a gain of 68,000,000 for the other countries. In the Mediterranean-Russian zone, consumption increased 17,000,000 short tons—8,000,000 in Russia and 9,000,000 in Mediterranean countries—and was primarily due to increased production rather than to an increase in imports. In the Southern Africa, Southern-Asia, Oceania zone, consumption increased 16,000,000 short tons. Northern Asia showed an increase of 30,000,000 tons, of which 22,000,000 was for the Japanese Empire. Southern America showed a decline of 4,000,000 tons. The most

[1] The proceedings of the conference, comprising all papers and discussions presented last November, have been published in two 900-page volumes by the Carnegie Institute of Technology, Pittsburgh, Pa.

COMPETITORS

Supremacy Between Bituminous Coal, and Water Power

significant factor is the comparatively small total increase, of only about 11 per cent in world consumption over 1913, and the larger relative gain in new areas.

The largest increases in production have come from the development of new coal-mine capacity in certain countries or parts of countries. The expansion in output in Germany, the Netherlands, and France is notable in Northern Europe. In the United States, the most notable increases have been in West Virginia and Kentucky.

With the increase in local coal production and the expansion of world fuel-oil consumption, the longer-distance international coal movements have remained stationary or have declined, and the distribution areas for coal have been shrinking closer to the centers of production.

RELATION OF BITUMINOUS COAL TO OIL AND GAS

While Mr. White covered the whole field of competition between coal and other sources of energy, other speakers covered each of the various phases of this competition. W. T. Thom, Jr., of Princeton University, Princeton, N. J., took up the subject of relationships of bituminous coal to oil and gas.

Minimum figures of available coal, oil, and gas reserves have a practical significance depending on the prospective rates of production of coal, oil, and gas for the next few years, and in his paper Mr. Thom considers the history of coal production and draws parallels between the histories of coal and of petroleum. The excessive production of oil occurred in part because of the small size of holdings, in part because of the terms of oil leases as usually written, and in part because of unfortunate judicial precedents which applied the law of wild animals to the capture of oil and gas.

The height in petroleum production was reached in 1929, but since then advancement in the ways of refining and using oil, increases in the competition of coal resulting from increased efficiency in use, and even more the growing competition of natural gas, have caused a flattening in the curve of oil consumption duplicating the post-war change in the coal curve.

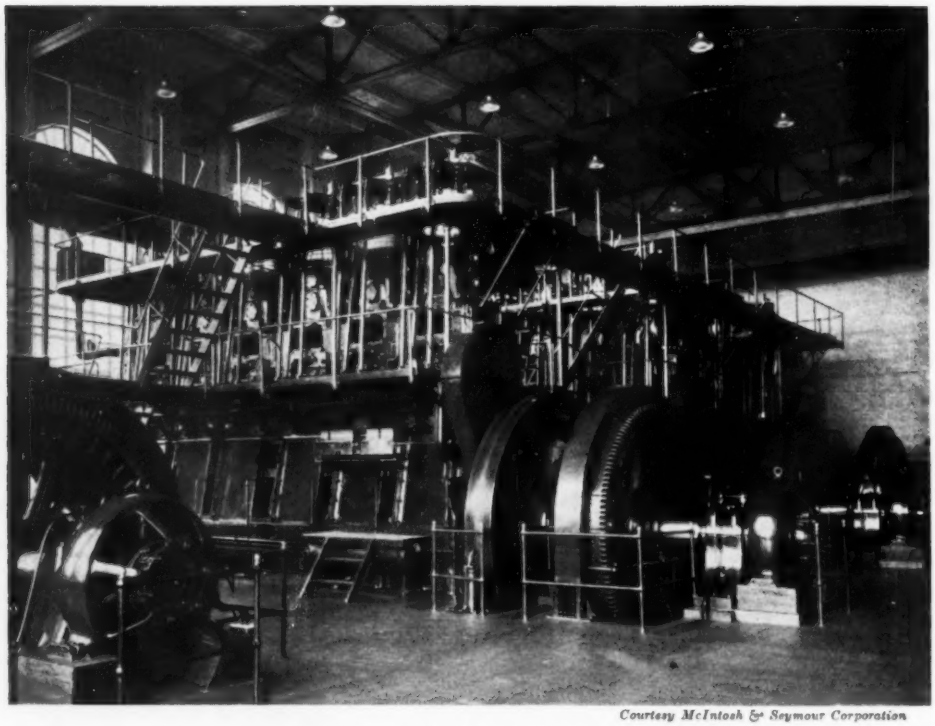
As regards gas, it would appear that the great development of natural-gas pipe-line systems has only begun, and that there will be great increases in the rates of gas production and consumption. Within the not-far-distant future, however, Mr. Thom believes that the market for gas will approach saturation, and, as costs of production rise, economies of use and the competition of coal will combine to give the curve of natural-gas consumption a gently downward slope.

The question as to what the coal producer can do in the face of continuing oil competition and increasing natural-gas competition is answered by saying that the hope for the coal industry lies in a particular recognition of the fact that we live in a world which is passing through an astounding economic transformation.

Modern science by directing the stored energy of the mineral fuels did away with the specter of famine. Our present troubles arise from overproduction of practically every imaginable commodity, and not from shortage. The ills of the coal industry cannot be corrected by speeding up production, and market capacity and not productive capacity must rule in the future. Even with proper solidarity and cooperative organization within the coal industry, it cannot unaided become stable and prosperous. Two other things are necessary, in the opinion of Mr. Thom. First, the removal of such taxation pressure as forces overproduction of coal or oil, and second, the elimination of orgies of overcompetition in oil-field development, such as, for example, the one which has just afflicted East Texas.

COMPETITION BETWEEN NATURAL GAS AND BITUMINOUS COAL

The competition between natural gas and bituminous coal was the



Courtesy McIntosh & Seymour Corporation

DIESEL ENGINES ARE DRIVING THESE GENERATORS

subject of two papers—one by Geo. I. Rhodes, vice-president of Ford, Bacon & Davis, Inc., of New York, and the other by R. B. Harper, vice-president in charge of research and testing, The Peoples Gas Light and Coke Company, Chicago, Ill.

According to Mr. Rhodes, the pipe lines now under construction or placed in operation since the year 1929 have an aggregate daily capacity of about a billion cubic feet.

When these new lines are loaded to capacity, there will be a further annual consumption of about 250,000,000,000 cubic feet, or an increase of more than 25 per cent above the recent maximum consumption. This figure of increase of annual delivery is based on an operation at favorable load factors, namely, 250 times the daily capacity, which corresponds to a load factor of 70 per cent. Gas fields, the available reserves of which are now reasonably known, will support such increased consumption of natural gas to attract new capital. Unless, however, there are large and important discoveries of new natural-gas reserves, it is difficult to see how new lines can be justified which will increase the consumption of natural gas to more than about double its recent maximum.

It should be noted that while much of the natural gas does replace coal, many of the large lines constructed in recent years have been built mainly with the idea of replacing fuel oil, which for years was the principal fuel consumed by the industries served. Also much of the natural gas used in homes is for conveniences that were neglected before the advent of natural gas.

A great many factors enter into the value of natural gas as compared with bituminous coal. It is quite as unwise to underrate its value as it is to overrate it as a competitive factor. For example, by giving the heating value of natural gas an incorrect value or by forgetting that whereas boiler installations burning coal have heavy losses because of high excess of air or improper furnace temperature, natural gas can readily be burned completely and without excessive furnace temperatures in all reasonably designed furnaces with from 7.5 to 15 per cent more air than that theoretically required for combustion, as compared to 20 to 30 per cent excess air for the most elaborate boiler installations. In evaluating natural gas in terms of coal there must be taken into account not only the factors affecting combustion and the cost of the fuel, but also the costs involved in handling, preparing, and firing the fuel and in the maintenance of the furnaces. In the case of boiler plants, taking the whole range from the smallest hand-fired industrial boilers to the largest, most elaborate installations involving water walls, air preheaters, economizers, and pulverized-fuel firing, the value of 1000 cu ft of natural gas as compared with $3 coal will range from 25 cents to 13 cents, or from about 8 per cent to about 4 per cent of the cost of a ton of coal.

Natural gas has particularly great advantages in metallurgical processes, and in some industrial-furnace uses where the ease of controlling temperatures is of paramount importance.

As regards the effect of natural-gas competition, Mr. Rhodes says that if the entire growth in consumption of natural gas other than for gas-field uses and for the production of carbon black could be considered as replacement of coal, then it would have replaced 21,000,000 tons. He criticizes certain estimates of costs of production and transportation of natural gas, including Government statistics thereon.

A comparison most unfavorable to natural gas is often made in the matter of cost of transportation. It has frequently been stated that it costs from three to four cents per 100 miles to transport 1000 cu ft of natural gas. These figures have been converted to the equivalent coal costs on the basis of exaggerated minimum gas values and have been figured at from $0.84 to $1.12 per equivalent ton of coal per 100 miles. These exag-

gerated costs have been compared with freight rates on coal running from 50 to 60 cents per ton per 100 miles, which at best are low coal tariffs.

The costs of transporting natural gas as well as freight rates are highly variable and are controlled by many factors other than the distance of transportation. The costs of transporting gas as well as freight rates vary not only with the character of the country through which the product is carried but with the quantity which is transported and with many other factors. Railroad freight rates in many instances seem to be controlled by considerations of expediency and competitive conditions as between mines and railroads for the service to a given market. The charges per ton per 100 miles for long hauls vary from as little as 39 cents to as much as 75 cents, and for short hauls of 100 miles from as low as $1.00 to as high as $1.90. The frequently quoted natural-gas transportation costs when converted on an average factor of 20,000 cu ft per ton run from 60 to 80 cents per equivalent ton of coal per 100 miles. These costs are typically representative of practice only a relatively few years ago, and cover all costs of transporting the gas with a return on the investment sufficient to attract capital.

Improvements in the art of transporting natural gas have been rapid, and further improvements are on the eve of being adopted. It is now possible to transport large quantities of gas at costs equivalent to 40 cents per ton of coal per 100 miles, and further improvements in materials and design are likely to be made which will result in the possibilities of transporting natural gas for long distances in large quantities at costs as low as the equivalent of 30 cents per ton of coal per 100 miles. This is illustrated by a chart in Mr. Rhodes's paper. With possible future gas transportation costs there is no economic limit to the length of a pipe line if the coal and the gas are the same distance from the market, and it is indicated further that in the future natural gas may be transported economically in competition with coal from sources 400 to 500 miles further away from the market than are the coal mines.

In discussing the same subject of competition between natural gas and coal, Mr. Harper starts with the general development of heat-energy demand and supply. He thinks that the peak period in the production of anthracite and bituminous coal considered at five-year intervals seems to have been reached in the year 1920, when the combined potential heat energy of these two commodities became about 17 quadrillion heat units. Since then these fuels have decreased—to less than 14 quadrillion heat units in 1930. In the same period petroleum increased from 3.3 quadrillion to approximately 5.7 quadrillion, and natural gas from 0.9 quadrillion to about 2.1 quadrillion Btu.

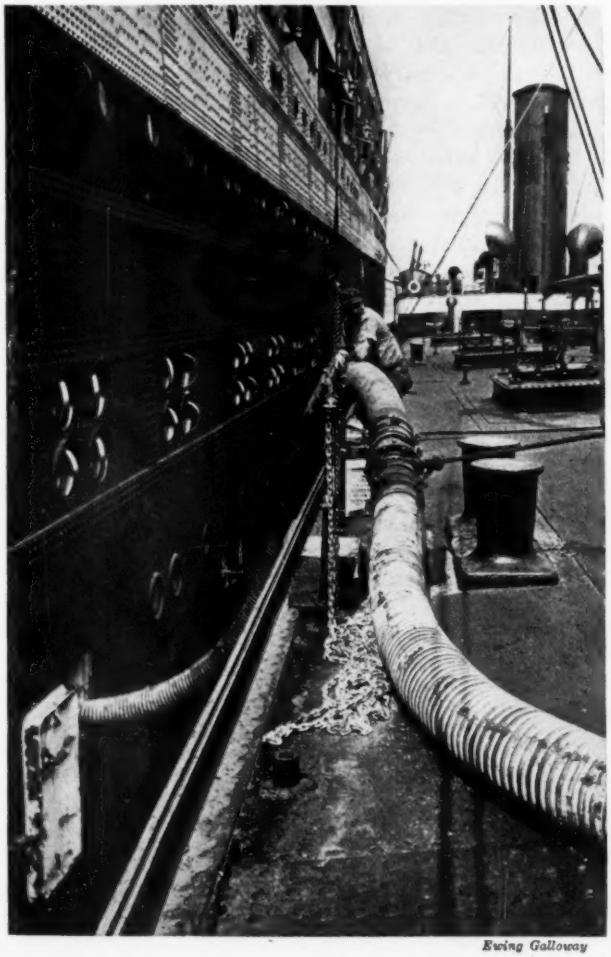
FACTORS DETERMINING THE COMPETITION BETWEEN FUELS

Mr. Harper also discussed the factors determining the competition between fuels. Among some of the more important of these may be mentioned the following: 1, Availability of fuel; 2, availability of equipment; 3, suitability of fuel; 4, suitability of equipment; 5, initial cost of equipment; and 6, operating cost.

As regards availability of fuel, he believes that there are still large supplies of both petroleum and natural gas which have been undiscovered. The latest estimates of natural-gas wells show that their potential supply is equivalent to a daily production of about 1,000,000 tons of bituminous coal. A most significant fact is the moving eastward of both the discovery and development of new gas fields and the moving of gas itself to markets in the eastern part of the United States, as indicated, for example, by the newly developed field in Tioga County, New York.

The progress of facilities for transportation of liquid and gaseous fuel is next indicated. In 1929, for example, 7400 miles of natural-gas pipe line were constructed, and in 1930 this figure was increased to 8300 miles, representing an estimated expenditure of about $100,000,000 for pipe alone.

At the present time natural-gas pipe lines actually extend or are in the process of construction from the more important gas fields to nearly every major metropolitan market or community. In at least one case an oil line 720 miles long is stated to have been leased for



Ewing Galloway

TAKING FUEL OIL ABOARD THE S.S. "MAJESTIC"

the purpose of conveying natural gas to various towns in a number of midwestern states. One of the most interesting sections of the paper deals with the operating cost.

To determine this Mr. Harper gives a table showing methods of comparison on the basis of the cost of heat as supplied by various fuels or energy sources at different unit prices covering the usual price ranges of certain commodities or sources of heat supply.

Comparisons on this basis, however, cannot be considered as absolutely guiding. Thus, for example, manufactured gas costs approximately the same as would good coal at $15 per ton. While actually such coal is available at $6 per ton, nevertheless thousands of house-heating installations are using gas. This is of course due to the collateral advantage which it possesses over coal for certain cases.

As regards the competition between natural gas and coal, Mr. Harper points to the same factors of development of engineering methods and economical means of transportation for natural gas, but considers both the competitive and non-competitive uses of the two fuels. Approximately 14 per cent of natural gas is consumed in the manufacture of carbon black and does not compete with bituminous coal, as the latter is not generally used for that purpose. About one-half of the total natural gas is consumed as fuel for petroleum-refinery and electric-generating-plant operations and in the general industrial manufacturing and domestic establishments.

Thus, we find in 1927, 952,000,000,000 cu ft of natural gas more or less directly competing with 262,242,000 short tons of bituminous coal for use in various industrial and domestic operations. Assuming for the moment that the 952,000,000,000 cu ft of natural gas had an average total heating value of 1000 Btu per cu ft and that the soft-coal equivalent would have had an average total heating value of 13,000 Btu per lb, we may estimate that, on the same basis of efficiency in use of these commodities the natural gas displaced an equivalent of about 37,000,000 short tons of bituminous coal, or about 7.5 per cent of the total consumption of soft coal in 1927. Upon the further assumption of much greater efficiency in the use of the potential heat of the gaseous fuel as compared with the solid, it appears that not more than 10 per cent of the soft-coal consumption in 1927 might be estimated to have been displaced by natural gas.

Of the theoretical loss in 1930 of 235,000,000 short tons in the consumption of bituminous coal from what it might be estimated to have been without the competition from natural gas, petroleum, and water power encountered from 1915 to 1930, only about 16 per cent can be directly attributed to natural-gas competition, whereas fuel and gas oils and also water power each theoretically replaced about 35 per cent of the loss, or a total of about 70 per cent, representing nearly five times that due to the gaseous fuel. Relatively small though it may have been, the growth in the competition between natural gas and coal for the available markets was inevitable. This is due to certain intrinsic advantages of the use of gaseous fuel in certain fields. From this point of view the following enumeration is of decided interest.

PRINCIPAL ADVANTAGES OF GASEOUS FUEL OVER BITUMINOUS COAL IN OPERATIONS INVOLVED IN THEIR COMBUSTION WITH AIR OR OXYGEN

1 *Delivery of Fuel:*
- *a* No delays in delivery (no waiting for fuel when needed)
- *b* Any supply delivered instantly as required (necessary supply always on hand)
- *c* No losses of fuel in transit from point of measurement to point of delivery (loss of fuel from cars, trucks, etc., in transit)
- *d* No change in physical condition of fuel from point of measurement to point of delivery (breaking up or contamination of fuel by refuse, etc.)
- *e* No damage to surrounding property due to delivery of fuel (damage to vegetation, floors, walls, etc.)
- *f* No dirt or dust in air due to delivery
- *g* No noise due to delivery
- *h* No labor required on premises to handle delivery of fuel
- *i* No notification ordinarily required to get delivery of fuel (telephone calls, purchase orders, letters, etc., unnecessary).

2 *Storage of Fuel and Ashes:*
- *a* No space required for storage of fuel or ashes (space available for rental or other purposes)
- *b* No investment necessary to provide storage facilities for fuel or ashes (no cost for bins, hoppers, containers, etc.)
- *c* No rental or expense for storage space or facilities for fuel or ashes.

3 *Handling of Fuel:*
- *a* No or less investment necessary to handle fuel to equipment
- *b* No or less labor required to charge fuel to equipment
- *c* Greater flexibility in charging fuel to equipment (rate of burning easily changed over wide range)
- *d* No dirt or dust due to fuel handling on premises
- *e* No excessive noise due to fuel handling
- *f* No inconvenience or damage due to fuel handling (interference with domestic or other activities).

4 *Preparation of Fuel:*
- *a* No investment for preparation of fuel necessary (no crushing, pulverizing, screening, equipment, etc.)
- *b* No labor necessary for fuel preparation.

5 *Condition of Fuel:*
- *a* Greater uniformity in heat value of fuel
- *b* Not subject to large variations in moisture content (coal sometimes containing much moisture, due to rain, etc.)
- *c* Not subject to contamination with miscellaneous foreign matter.

6 *Utilization of Fuel:*
- *a* Greater flexibility in application of fuel (greater variety of flames or heat applications possible)
- *b* Greater range in temperature possible
- *c* No smoke produced
- *d* No labor required for ashes or clinkers formed (no barring of clinkers, shaking of grates, dumping of ashes necessary)
- *e* No soot, tar, or ash deposits in fuel-utilizing equipment or chimney requiring frequent cleaning and causing inefficient operation or damage to equipment
- *f* No fly ash discharged from chimney or equipment resulting in damage, complaints, etc.
- *g* Much less sulphur in various forms discharged from chimney or equipment, resulting in damage, complaints, etc.
- *h* Less or no labor or supervision required in operating equipment with fuel
- *i* Usually more efficient use of total heating value of fuel
- *j* Fuel easier to ignite or start burning (no wood or auxiliary fuel needed to start operation)
- *k* Fuel easier to burn completely (no unburned fuel lost in ashes)
- *l* Less losses due to intermittent operations.

7 *Handling of Residues:*
- *a* No investment necessary to handle ashes, soot, etc. (conveyors, shovels, soot removers, etc.)
- *b* No labor required for removal and disposal of ashes, soot, etc.

c No expense for trucking or taking away ashes, etc. from premises
d No dirt or dust due to handling residues
e No excessive noise due to handling residues
f No inconveniences or damage due to ash or soot handling.

8 *Payment for Fuel:*
a No payment usually made for fuel until after instead of before being used (gas is only paid for after it is all used, while coal is usually paid for before it is all consumed).

9 *Maintenance of Fuel-Utilization Equipment:*
a Less maintenance, repair, or replacement of equipment parts necessary
b Maintenance service usually more readily available.

10 *Work Performed or Service Rendered by Fuel:*
a Service rendered with no or less inconvenience
b Work more efficiently performed
c Work done or products produced of better quality
d No or less loss by inferior or rejected products
e Work done or service rendered more speedily
f Performance of work requires less attention and no hard labor
g Performance of work may be accomplished under better working conditions.

It is rather interesting here to note that practically all of the speakers discussing competition between coal and other forms of energy assumed a mild, almost apologetic attitude, much as if they really hated to compete with bituminous coal but could not help doing so. This may be partly explained by the fact that the conference at which the papers and addresses were presented was primarily called in the interests of bituminous coal, and that the majority of the audience were engaged in the coal business. It may also have been partly due to the fact that the coal business represents a tremendous investment and is a very important factor in the life of the country, and hence deserves all kinds of support. Whatever may have been the reason for this attitude of avoiding emphasis on factors competitive with coal, it was nevertheless rather strikingly in evidence.

ECONOMICS OF WATER POWER VS. STEAM POWER

The economics of water power versus steam power formed the subject of a paper by Geo. A. Orrok, of Orrok, Myers, and Shoudy, New York City. The first point that the author made was that water power is not free. Nature supplies the falling water, but some one must pay the cost of harnessing it, converting it into power, and transmitting it to the market where it can be used. Not only is water power not free, but, as will be shown later, it is not even an exceptionally cheap source of power. Moreover it is not abundant. Statistics regarding the availability of water for power purposes for all portions of the United States have been collected by the Geological Survey, and from these it would appear that while the average annual rainfall over the entire surface of continental United States represents a huge amount of water (equivalent to a rainfall of 6.6×10^6 cu ft of water per sec), only a small portion of this water can be utilized, as drinking water, vegetation and evaporation, ground-water storage and chemical combination utilize a large portion of the water supply, reducing the average run-off to perhaps 35 per cent of the rainfall. The available figures for the average elevation above sea level and average rainfall do not take into account the distribution of the high areas and the low areas, and as a matter of fact certain low-lying areas along the Gulf of Mexico where the elevation is too small for using water for power generation have an excessive rainfall, while the high plateaus have a very meager one. When a weighted rainfall versus height above sea level is calculated, the correction factor seems to be of the order of 64 per cent.

There are other factors which affect availability of water. For example, rivers like the Mississippi and Colorado each have a large alluvial plain, where the slope of the water surface is so small that it is nearly impossible to utilize for power purposes falls much smaller than 10 ft to the mile, and other factors make large stretches of medium fall unavailable. Furthermore, the distribution of the rainfall through the various months of the year is not uniform, which means that only a portion of the total rainfall can be utilized for normal power generation.

The conclusion to which Mr. Orrok comes is that if all the run-off of the United States could be utilized, the maximum output to be expected would be 586×10^9 kwhr, and this output if generated by steam at 1.67 lb per kwhr, the average central-station rate of 1930, would require 437×10^6 tons of coal, or about 73 per cent of the coal annually used in the United States. This estimate is liberal, and the estimate of the Geological Survey is less than one-third as large.

The estimates of the Geological Survey have been made on a slightly different basis and only include sites where the estimated cost did not exceed $500 to $600 per kw. Their estimates are:

20,700,000 kw	90 per cent of the time	163,000,000,000 kwhr
32,800,000 kw	50 per cent of the time	144,000,000,000 kwhr

or in round numbers, 160,000,000,000 kwhr, equivalent to 120,000,000 tons of coal at the 1930 rate of 1.67 lb per kwhr.

The Geological Survey reports as of January 1, 1931, a hydraulic installation of 8,799,000 kw which should yield something between 71,000,000,000 kwhr and 38,500,000,000 kwhr at the above ratio. On this installation we actually generated in 1930 about 33,000,000,000 kwhr. Using this ratio and the Survey's estimate of all possible plants irrespective of cost, we may expect roughly 123,000,000,000 kwhr per year as the maximum possible output from water power in the United States, at a cost three to four times larger than the equivalent output of steam power. We already use the equivalent of twice this figure in mechanical power generated by steam in this country, and our central-station and industrial power amounted to about this same figure of 123,000,000,000 kwhr in 1928. Hydraulic power has been running from 40 to 33 per cent of the central-station power, and this proportion will become smaller as the newer developments become more costly and further away from markets.

Obviously the determining factor will be the cost of hydraulic developments. Today the average of all undeveloped sites has been variously estimated as running from $300 to $600 per kw. This cost includes the real estate and water rights, the dam, head and tail races, and power-station buildings with the gates, valves, and screens, the penstocks and surge tanks, turbines, generators, governors, and switchboard. As additional costs we must include step-up and step-down transformers, rights of way, and transmission lines, and the substations with transformers, condensers, and switching apparatus to the market, which may easily add $100 per kw to the above figures.

Fixed charges make up a large portion of the total cost of hydroelectric energy, while the operating cost is small. The kilowatt-hour charge depends on the flow of the stream and on how careful the flow, pondage, and storage can be adjusted to the demand. In any event the output is a function of the run-off, which varies almost 50 per cent from year to year.

Mr. Orrok exhibited a diagram showing the unit cost of hydroelectric power in cents per kilowatt-hour delivered as a function of the investment per delivered kilowatt of maximum demand. Here the fixed charges make up somewhere between 90 and 95 per cent of the cost of water power, and it is pointed out that the prime cost of development has been constantly increasing.

Steam power in the United States has been increasing very rapidly. In the central-station field many of the newer and better plants are producing electricity at the rate of about 1 lb of coal per kwhr, while the best use only about 0.9 lb per kwhr. We may confidently expect thermal efficiencies as low as 11,000 Btu per kwhr in the near future on a base-load plant with a high load factor.

The costs of steam power are less variable than those of water power, but even here the effect of load factor on cost is quite marked, although fixed charges do not usually amount to more than 45 per cent of the total cost. Mr. Orrok's paper presents a careful analysis of costs of power generation per kilowatt-hour for various load factors and unit prices of coal. The author assumes an average cost for modern stations of $100 per kw, although the actual costs have been running from about $115 to as low as $70 per kw. This gives cost figures for various load factors as shown in Fig. 1.

The steam plant is not yet approaching its ultimate efficiency, while the hydro plants are very near the ultimate efficiency, 92 to 94 per cent, leaving very little chance for improvement.

With the steadily increasing cost of water rights, real estate, hydro-construction, and transmission lines, the cost of hydroelectric power will attain higher and higher values, shifting the economic balance further toward steam power. On the Pacific slope, oil is being quoted at $2 per ton, while there are sites in the East where $1 coal is available. Thus each proposition is unique, to be considered by itself as to cost, layout, markets, water and fuel supply, rainfall, and storage, but when the costs are known it then becomes a question of how long the static condition is to continue. Here the knowledge of the engineer, the genius of the executive, and the judgment of the financier must combine to determine the proper decision

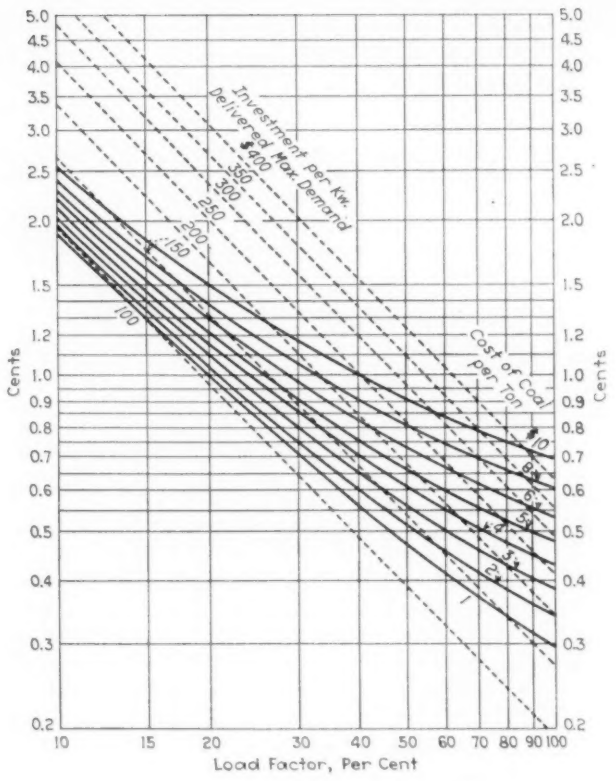


FIG. 1 COSTS OF POWER GENERATION

Two other factors may be involved in the matter of competition between fuels. The first of these is the possibility of using coal in the form of fine powder as fuel in Diesel engines. This would bring back to coal a certain region of power generation where oil reigns supreme today.

The second possibility is that of conversion of coal into other forms of fuel, such as fuel oils and fuel suitable for explosion-type engines. A representative effort in this direction is shown by the Bergius hydrogenation process. This has not so far created a situation where coal can compete in cost of performance with native oil, as, for example, in the United States, but it is apparently already becoming of economic importance in such countries as Germany which have to import their oil. Here a considerable influence will probably be exerted by the possibility of obtaining particularly valuable by-products from the conversion process.

Finally, a third factor may be mentioned, which is along the lines discussed by Mr. Orrok in his paper on competition between water power and coal, namely, that the possibilities of using coal as a fuel are very far from having been exhausted, and every improvement is apt to strengthen the competitive position of coal. This is illustrated particularly by such developments as the use of powdered coal and higher-pressure steam in the locomotive and marine fields.

The National
HYDRAULIC LABORATORY[1]

Hydraulic Features—Reasons for Design Adopted

By HERBERT N. EATON[2]

CONSTRUCTION of the National Hydraulic Laboratory at the Bureau of Standards was commenced during the latter part of April, 1931, and the building was completed during March of this year. Now that the laboratory has become a reality, a description of its hydraulic features, together with a statement of the reasons for the particular design adopted, would seem to be timely.

The history of the movement to secure the establishment of a hydraulic laboratory at the Bureau of Standards and of the events that led up to the adoption of the final design has been published elsewhere[3] and will not be repeated here. Instead, this article will be confined mainly to a consideration of technical questions of the design.

FUNCTIONS OF THE LABORATORY

The general features of the design naturally depended upon the functions which the laboratory is to fulfil. The bill establishing the laboratory states in part:

> There is hereby authorized to be established in the Bureau of Standards of the Department of Commerce a national hydraulic laboratory for the determination of fundamental data useful in hydraulic research and engineering, including laboratory research relating to the behavior and control of river and harbor waters, the study of hydraulic structures and water flow, and the development and testing of hydraulic instruments and accessories.

The functions of the laboratory clearly fall under the following heads: fundamental research in hydraulics, tests of hydraulic structures (model tests), and tests and development of hydraulic instruments and accessories.

The following partial list of research problems that has been proposed for immediate study in the National Hydraulic Laboratory will give some idea of what may be undertaken during the first few years and also of the provisions that had to be made in the design of the laboratory for this work: coefficients for orifices and weirs of all types; study of the hydraulic jump; flow around bends in pipes and open channels; laws of movement of detritus; losses in pipe lines and in pipe fittings; wave phenomena; cavitation; scale effects; etc.

Undoubtedly there will also be a very great demand for model tests of particular hydraulic structures. The Bureau of Reclamation in particular has already indicated many special and general problems of this nature that it wishes to see taken up by the new laboratory at the earliest possible date. Model tests of a general nature have also been proposed—for example, flow in chutes and transition sections; erosion below dams; studies of siphon spillways; the entrainment of air in tunnels, backwater due to various structures; silting of canals; and entrance and exit losses in hydraulic structures.

The facilities at the Bureau of Standards for testing hydraulic instruments have been decidedly limited. The equipment for testing current meters in still water is adequate, but provision will now be made for testing them also in flowing water. The Bureau now has facilities for testing water meters up to the $1^1/_2$-in. size, and facilities will be provided for testing up to the 6-in. size in the new laboratory. Provision will also be made ultimately for testing venturi meters up to a 12-in. diameter. The existing 2-ton weighing tank will be supplemented in the new laboratory by several other weighing tanks, arranged in pairs with diverters, so that continuous weighings can be made over a period of time.

TYPE OF LABORATORY CHOSEN

There were several sets of alternatives to be considered in the choice of the type of laboratory to be built. It had to be decided, first, whether the laboratory should be an open-air or an enclosed one, that is, whether the models should be built and the investigations conducted out-of-doors or inside a building; secondly, whether the laboratory should comprise merely a large open floor with the necessary basins to supply and measure the water, or considerable fixed equipment should be provided; and, thirdly, whether provision should be made for large-scale testing, requiring flows of perhaps several hundred cubic feet of water per second, or only for relatively small flows.

Indoor Versus Outdoor Laboratory. Many engineers appear to have the impression that large-scale tests invariably involve models which are too large to be built indoors. This is not true in general. Obviously, both the size of the natural structure and the scale of the model are determining factors. The author has frequently

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[1] Publication approved by the Director of the Bureau of Standards of the U. S. Department of Commerce. Part 2 will appear in an early issue.

[2] Hydraulic Engineer, U. S. Bureau of Standards, Washington, D. C. Mem. A.S.M.E.

[3] "The National Hydraulic Laboratory at the Bureau of Standards," by George K. Burgess, Director, Bureau of Standards; *Civil Engineering*, vol. 1, no. 10, July, 1931, p. 911.

Courtesy of C. P. Kittredge

WASTE CHANNEL AND CONTROL STATION IN THE OBERNACHTAL, BAVARIA

seen models built indoors to a 1:10 scale, and even occasionally to a 1:5 scale when the structure or portion of the structure copied in the model was relatively small.

There are two well-known open-air hydraulic laboratories in Europe, one at Marquardt, near Berlin, which is operated by the Versuchsanstalt für Wasserbau und Schiffbau in Berlin, and the other in the Obernachtal, near Munich, which is operated by the Forschungsinstitut für Wasserbau und Wasserkraft. It will be instructive to examine the reasons for the establishment of each of these laboratories.

The open-air laboratory at Marquardt was built because of the necessity of conducting tests on models which were too large to be housed in the Berlin laboratory. Tests have been made at Marquardt only when it was not feasible to conduct them indoors. This laboratory is an outgrowth of the laboratory in Berlin, and in no sense replaces it. Statements that the Berlin laboratory, or any other indoor hydraulic laboratory, is being replaced by an outdoor one[4] are wholly erroneous. Rather, the indoor laboratories are being supplemented by outdoor laboratories for special problems.

The purpose of the outdoor laboratory built in the Obernachtal by the Forschungsinstitut für Wasserbau und Wasserkraft is entirely different from the above. In the words of Dr. Hubert Engels:[5]

"The Forschungsinstitut für Wasserbau und Wasserkraft, which commenced its work near the close of 1926, will occupy itself primarily with investigations of large-scale models and in Nature itself. The work therefore consists essentially in the study of those problems which require large-scale tests for their successful solution. Furthermore, in those cases in which small-scale tests suffice to give trustworthy results for predicting conditions in the full-scale structure, it is desirable to compare the results obtained with the model and in Nature in order to determine the validity and the limits of the laws of similarity as here used.

"In order to solve these problems the Forschungsinstitut will conduct tests on the structures of the actual water-power installations, as well as in its own laboratory."

The Forschungsinstitut utilizes a piece of land adjacent to the diversion canal that carries water from the Isar River to the Walchensee. Water to the extent of 8 cubic meters per second (280 cubic feet per second) can be diverted into the experimental channels of the outdoor laboratory, and then returned to the canal further downstream.[6]

Such a design would not be suitable for the National Hydraulic Laboratory because it makes no provision for the small-scale tests and general research which, it is expected, will constitute perhaps 90 per cent of the work of this laboratory. Consequently, it was considered desirable in designing the laboratory to go as far as possible in the direction of providing facilities for large-scale tests, but not to sacrifice the facilities for small-scale work to attain this end.

Finally, no one who is familiar with hydraulic experimenting would wish to conduct experiments in the open if they could be conducted indoors, because of the disturbing effects of wind, sun, and rain, and because in

[4] Such statements were made during hearings before the Rivers and Harbors Committee of the House of Representatives by opponents of the National Hydraulic Laboratory bill. The author speaks from first-hand knowledge, since he spent more than a year working in the German laboratories.

[5] Forschungsinstitut für Wasserbau und Wasserkraft e.V. München, Mitteilungen, Heft 1, Published by R. Oldenbourg, Munich and Berlin, 1928.

[6] "Great German Hydraulic Laboratory," by Hunter Rouse, *Civil Engineering*, vol. 1, no. 8, May, 1931, p. 715.

Courtesy of H. Kramer

INTERIOR OF RHINE RIVER LABORATORY, SHOWING RHINE MODEL, TECHNICAL UNIVERSITY OF KARLSRUHE, GERMANY

most localities the work must be halted during the winter season.

ENGINEERING TESTS VERSUS EXPERIMENTAL RESEARCH

For purely engineering tests of hydraulic structures, a laboratory similar to the Versuchsanstalt in Berlin, with its main test floor 92 meters (300 ft) long and 14.5 meters (48 ft) wide, but with little fixed equipment, is excellent. However, if the laboratory is to be adapted to scientific research it will be very convenient to have certain fixed equipment in addition to the ever-necessary supply and measuring basins, such as fixed pumps, constant-level tanks, weighing tanks, and flumes of various sizes.

Consequently, the most advantageous conditions for conducting tests of an engineering nature are to a certain extent contradictory to those for conducting scientific research, and the only way in which the laboratory can be adapted to both lines of work is to make it so large that the conditions for both can be included.

LARGE-SCALE VERSUS SMALL-SCALE TESTS

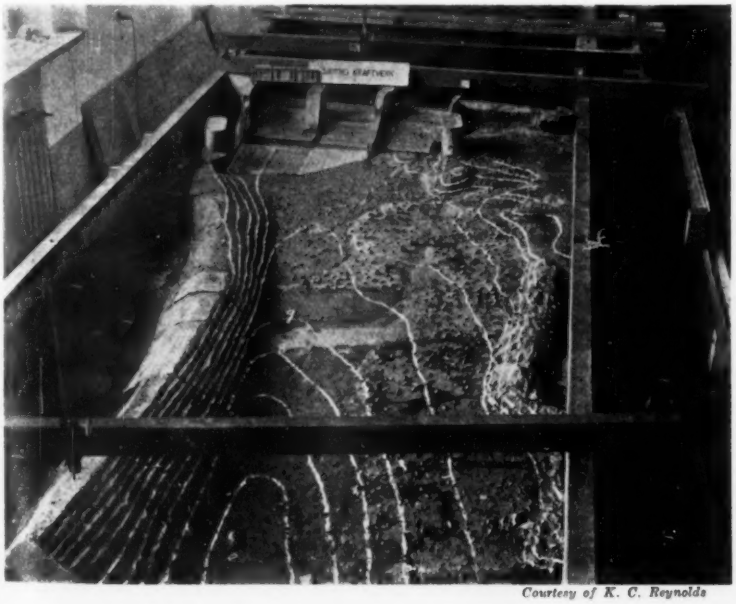
The principal advocate of small-scale tests is Dr. Theodor Rehbock, of Karlsruhe, Germany. His attitude can perhaps best be understood by a quotation: "In experimenting with hydraulic structures,[7] the smallest possible scale of the model and the greatest possible accuracy of the model and of the observations should be striven for. The limiting model size is that for which the accuracy of the observations begins to be affected.[8] The determination of this limit appears to be of particular importance."[9]

Dr. Rehbock recognizes clearly that the model must not be so small that disturbing factors will affect the similarity of the phenomena in the model to those in the full-sized structure. However, he makes the models as small as is permissible, because this increases the accuracy of his measurements, particularly the measurement of flows, as well as the ease and rapidity with which they can be made.

The attitude of the European so-called proponents of large-scale tests has occasionally been stated erroneously by American engineers. The European proponents of large-scale tests believe that Dr. Rehbock frequently reduces the scale of his models too far. They do not, however, maintain that model tests should be conducted at the largest possible scale, but rather at the smallest possible scale that will permit the results to be scaled up to Nature correctly. In support of this statement the author offers the following quotation from a letter written to him by a German engineer who is in charge of one of the most important hydraulic-structures laboratories in Europe: "Because of the cost of large models and the difficulties involved in handling large quantities of water, the object of such experimentation is not to choose the model scale as large as possible, but rather as small as the transferability of the model results permits." The present tendency in Europe is to study a given problem with geometrically similar models built to different scales, in order to determine how small a scale can be made to yield sufficiently accurate information.

Courtesy of C. P. Kittredge

CONCRETE RESEARCH CANAL IN THE OBERNACHTAL, BAVARIA, LOOKING TOWARD THE MEASURING BASIN



Courtesy of K. C. Reynolds

MODEL OF SITFORS DEVELOPMENT IN THE HYDRAULIC STRUCTURES LABORATORY, ROYAL TECHNICAL UNIVERSITY, STOCKHOLM, SWEDEN

[7] Dr. Rehbock refers here to tests of the entire structure, as contrasted with tests made on a small portion of the structure; for example, the entire structure might represent a hydroelectric installation, while a partial model might represent a section of a spillway in such a project.

[8] That is, by effects that do not obey the scale law assumed for the model.

[9] "Der Massstab wasserbaulicher Modelle," by Th. Rehbock, Tagung der Vorstände der Wasserbaulaboratorien, Berlin, 1929.

Courtesy of H. Kramer

HYDRAULIC TESTING FLUME AT LABORATOIRE DU SAULCY, SOCIÉTÉ HYDROTECHNIQUE DE FRANCE, METZ, FRANCE
(Designed and built under direction of Lt. H. W. Ehrgott, Corps of Engineers, U. S. A., in 1931.)

Small-scale tests possess the advantages that the models can be cheaply and easily constructed, modifications can be made quickly, the observations of quantity of flow can be made with relatively great accuracy, the time required for the tests is relatively short, the space required for the tests is not great, and the power required to circulate the water is small.

Perhaps the most important one of these factors is the time required to conduct the tests. Large-scale tests require much more time than small-scale, and since the construction engineers are always in a hurry, the time necessary for the construction and test of a large hydraulic model may be prohibitive.

COST A CONSIDERATION

In addition to the time factor, the cost must also be considered. It is probable that the cost of the model and the necessary equipment increases at least with the cube of the model scale. This is not difficult to understand when it is remembered that for most of the types of test the flow increases with the 2.5 power of the linear scale.

In view of the disagreement abroad on this subject and the lack of experience here, it was unquestionably advisable to plan the National Hydraulic Laboratory for large-scale tests. Another reason for this decision was the fact that many practical engineers are skeptical of model tests, and hence it is desirable to prove their validity, when conducted properly, by tests of a series of geometrically similar models built to different scales and up to the largest of them which it is feasible to construct.

The foregoing considerations, it is believed, make it clear why it was decided to enclose the laboratory completely, to provide both a large area of unobstructed floor space and a considerable amount of fixed equipment, and, lastly, to make provision for circulating large quantities of water.

Courtesy of H. Kramer

INTERIOR OF MAIN HALL OF NEW HYDRAULIC LABORATORY, FEDERAL INSTITUTE OF TECHNOLOGY, ZURICH, SWITZERLAND

Fairchilds Aerial Surveys, Inc., N. Y. C.

DENSE SMOKE AND HEAVY FOG ALL BUT HIDE THE METROPOLIS FROM THE AIRPLANE PILOT'S VIEW

ABATING THE SMOKE NUISANCE

Experiments With Steam-Air Jets Applied to Boiler Furnaces

By A. C. STERN[1]

THE smoke nuisance caused by improperly designed hand-fired furnaces burning bituminous coal may, to a certain extent, be abated by the use of steam-air jets to supply over-fire air and over-fire turbulence. This has been known since at least 1880, when the first devices of this type were patented and marketed. Since then almost every smoke-abatement campaign has experienced a period during which steam-air jets were installed on a number of offending furnaces.

Steam-air jets are devices by means of which steam at boiler pressure is injected into the furnace through nozzles in such a manner that the steam serves to induce or aspirate a relatively large flow of high-velocity air along with it. In 1927, at Case School of Applied Science, DuPerow and Bossart thoroughly investigated the various elements entering into the design of steam-air jets. These elements included the effect of varying steam pressure, nozzle size, nozzle shape, nozzle location with respect to the air-induction tube, air-induction-tube diameter, and air-induction-tube length. Their conclusions as to the most satisfactory design are now included in the design of the jet recommended and used by the Smoke Departments of Cleveland, Ohio, and Hudson County, N. J. (Fig. 1).

This design of jet, and in fact any design of simple jet, will not work very efficiently on less than 50 lb gage steam pressure. It was also ascertained that as the steam pressure applied to the jets was increased, both air entrainment and resulting turbulence increased until the pressure reached about 100 lb gage. Beyond 100 lb, air entrainment started to decrease rapidly. Therefore it is advisable to throttle high-pressure steam down to 100 lb or less at the jet nozzle. Under these

[1] Stevens Institute of Technology, Hoboken, N. J.

conditions of operation, this form of jet will induce about 20 lb of air per pound of steam, and will create an air velocity effective for turbulence (measured 3 ft from the jet) of about 3000 ft per min.

CURRENT PRACTICE IN USE OF JETS

Current practice calls for the use of at least three steam-air jets per furnace, and as many more as are required by the empirical rule of one jet for every 200 to 250 sq ft of boiler heating surface. Jets placed on the furnace front wall are usually spaced on about 12-in. centers and are pointed to hit about 4 in. above the intersection of the grate and the bridgewall. In general, the placement of jets should be such as to cause maximum turbulence of the gases rising from the fuel bed. On the piping that connects the steam nozzles to the steam

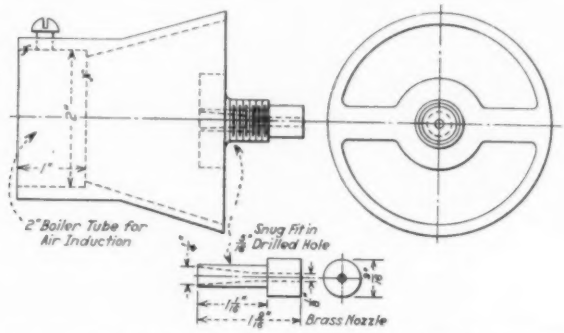


FIG. 1 STEAM-AIR JET WITH SELF-CLEANING NOZZLE

header, some provision must be made to eliminate condensation that is liable to form during the periods the jets are not in use. This may be accomplished by locating the quick-opening valve near the header or by using steam traps.

In operation, jets are not used continuously unless they are installed to reduce smoke from a stoker-fired or chain-grate furnace. They are turned on just before firing, and are left on long enough to leave a clear stack after they have been turned off again. On several tests made, the interval during which jets were on averaged about three minutes for each firing with bituminous coal containing about 20 per cent of volatile matter. The time would increase with coal of higher volatile content. However, the efficiency of the jets as smoke-reducing devices would remain about the same.

RESULTS OF TESTS

Recently it was found desirable to obtain quantitative information as to the effect of using steam-air jets on overall boiler efficiency. The only information that could be gleaned from a search of the literature concerned two tests made at the University of Tennessee by Switzer in 1910. These indicated an increase of about 10 per cent in boiler efficiency due to the use of the steam jets. The percentage of the total steam generated that is consumed by the jets, as usually reported, ranges from 5 to 15 per cent.

Because the available data were so incomplete, the Department of Smoke Abatement Research of Stevens Institute of Technology sponsored several tests early in 1931 in conjunction with the Hoboken Marine Shops of the Pennsylvania Railroad. These tests were carried out under the direction of Col. Elliott H. Whitlock, and were run by Messrs. P. B. Christensen and O. R. Strahl in conjunction with the author. They showed that the amount of steam consumed by the jets amounted to between 1 and 2 per cent of the total steam generated; or in these tests to about 0.05 lb of steam per pound of coal fired. The heat loss occasioned by bleeding this steam from the boiler and superheating it inside the furnace amounted to about 0.5 per cent of the heat in the coal.

The best overall increase in boiler efficiency noted in these tests was about 10 per cent, but the increase in efficiency that may be expected when jets are applied to any hand-fired furnace will not necessarily be the same, and will depend largely on the overall efficiency itself prior to their installation.

In these tests, no other attempt was made to increase the overall boiler and furnace efficiency, but it is firmly believed that with the same careful handling in both cases the addition of steam-air jets will allow operation of a poorly designed furnace at a higher overall efficiency, and materially reduce the smoke.

Measurement of Smoke Density

THE solids held in suspension in the air consist of a number of different materials, and while smoke and fly ash may be in the majority in certain localities, particles of soil, rock, brick, rubber from automobile tires, and various organic materials are generally also present. The proportions of these materials suspended vary according to the size and nature of the industrial activities of the community. While clouds of these impurities may vary in color, all of them filter out some of the ultra-violet rays from the sunlight, the amount depending on the concentration of such impurities in the atmosphere. In measuring the solid emission from smokestacks the usual method is by color shade comparison. Accurate estimation of the density of such smoke (including any accompanying fly ash) by such comparison is of decidedly questionable accuracy, due to several uncontrollable factors. These factors include the difference in color effects of different thicknesses of smoke, the direction of the wind with respect to the observer, the effect of reflected light as well as of transmitted light, the presence or absence of direct sunlight, and the difference in the effect of black particles as compared with the lighter-colored ones, such as pulverized-coal fly ash. If smoke from metallurgical processes is excluded, the case is somewhat simplified, since this eliminates the majority of the red, brown, and certain of the white particles, and confines the comparison to the blacks and grays of the stack discharge. A method in common use compares the stack emission with standard charts, such as the Ringelmann smoke chart.—W. A. Carter in *Power*, Nov. 10, 1931, p. 678.

LUBRICATION RESEARCH

of The American Society of Mechanical Engineers[1]

By A. E. FLOWERS[2] AND M. D. HERSEY[3]

IN THE United States, lubrication research has been actively promoted by a committee of The American Society of Mechanical Engineers, known as the Special Research Committee on Lubrication. Especial attention has been given to the more fundamental mechanical and physical problems.

This Committee endeavors to coordinate its own experimental program with all other closely related work that may be in progress, both at home and abroad, so as to obtain the maximum information with a given expenditure of funds, and to avoid duplication except where this may be definitely useful as a check on the accuracy of observations. Accordingly, this Committee very keenly welcomes the opportunity to participate in a Congress where information can be exchanged between widely separated groups of investigators, and hopes that such meetings may be continued in the future.

As the American Committee, at the present time, is particularly interested in the problems of oiliness and thin-film lubrication (*onctuosité; influences moléculaires*), it seems most appropriate that the invitation to take part in the Congrès du Graissage should come from so successful an investigator in this field as Paul Woog, whose treatise (1)[4] must be constantly kept within reach for consultation.

REPRINTING OF EARLIER CONTRIBUTIONS

To aid in avoiding duplication resulting from inaccessibility of published investigations, the Committee has been asked to compile a representative collection of the earlier American publications that are now out of print. Fourteen papers were selected, and are to be reprinted in a single volume at the first opportunity. The list includes papers by Albert Kingsbury on the friction of screws (2), on experiments with an air-lubricated journal (3), on a new oil-testing machine (4), on tests of large shaft bearings (5), and the first published report of the Committee (6), of which Mr. Kingsbury served for a long period as chairman. It includes the paper by A. W. Duff on empirical formulas for viscosity as a function of temperature (7); and two papers by A. E. Flowers, one on viscosity measurement and a new viscosimeter (8), the other on a cylinder friction and lubrication testing apparatus (9). The remaining papers are by M. D. Hersey, on the laws of lubrication (10, 11), and on the torsion and rolling-ball viscosimeters and the effect of pressure on viscosity (12); by H. A. S. Howarth on thrust bearings (13, 14); and by L. J. Linsley on critical bearing pressures causing rupture in lubricating films (15).

ORGANIZATION AND PUBLICATIONS OF THE AMERICAN COMMITTEE

The Lubrication Committee was organized in 1915 to investigate the fundamental problems of lubrication phenomena, to formulate the results of investigations previously made, and to keep in touch with contemporary research in this field. It deals with a subject of basic importance in many different branches of engineering, including railway and marine transportation, power generation, and manufacturing industries.

The Committee is made up of eleven members.[5]

The Committee has published five progress reports. The last two include extensive bibliographies (16, 17), and have been reprinted with discussions that were contributed at the 1927 and 1930 Annual Meetings of the Society. Five articles on lubrication research were published in response to specific requests (18–22). In addition, several papers presented at meetings of the Society, not originating within the Committee, were discussed by members of the Committee upon request, and have been published in full together with discussion (e.g., 23 and 24).

Eleven investigations conducted by the Committee in cooperation with the De Laval Separator Company, Kingsbury Machine Works, Pennsylvania State College, and Westinghouse Company have been presented at various meetings of the Society (25–35).

Six investigations conducted in the laboratories of the Massachusetts Institute of Technology, Harvard University, Johns Hopkins University, and United States Bureau of Standards, that were supported either wholly or in part on funds contributed to the Committee by American industries and by the Engineering Foundation, have been reported in recent publications (36–41).

EXPERIMENTAL WORK IN PROGRESS

While recognizing many other problems that are awaiting solution, the research program of the Committee is, at the

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[1] Statement prepared for the Congrès du Graissage, Strasbourg, France, July 20–26, 1931, and presented by Mr. Winslow H. Herschel on behalf of the A.S.M.E. Special Research Committee on Lubrication.

[2] Engineer in Charge of Development, The De Laval Separator Company, Poughkeepsie, N. Y.; Chairman, A.S.M.E. Special Research Committee on Lubrication.

[3] Research and Development Department, Vacuum Oil Company, Inc., Paulsboro, N. J.; member, and former Chairman, A.S.M.E. Special Research Committee on Lubrication.

[4] References to literature are given at the end of this paper, corresponding to the reference numbers cited in parentheses throughout the text.

[5] Dr. A. E. Flowers, *Chairman*, Engineer in Charge of Development, The De Laval Separator Company, Poughkeepsie, N. Y.

Prof. Earle Buckingham, *Secretary*, Professor of Engineering Standards and Measurement, Massachusetts Institute of Technology, Cambridge, Mass.

Mr. L. P. Alford, Vice-President, The Ronald Press, New York, N. Y.

Prof. L. J. Bradford, Professor of Mechanical Engineering, Pennsylvania State College, State College, Pa.

Dr. H. C. Dickinson, Chief, Heat and Power Division, Bureau of Standards, Washington, D. C.

Mr. M. D. Hersey, formerly Chief, Friction and Lubrication Section, Bureau of Standards, Washington, D. C.

Mr. H. A. S. Howarth, Vice-President and General Manager, Kingsbury Machine Works, Inc., Philadelphia, Pa.

Prof. G. B. Karelitz, Associate Professor of Mechanical Engineering, Columbia University, New York, N. Y.

Mr. (formerly Professor) Albert Kingsbury, President, Kingsbury Machine Works, Inc., Philadelphia, Pa.

Dr. B. L. Newkirk, Engineer, Research Laboratory, Mechanics Section, General Electric Company, Schenectady, N. Y.

Prof. A. E. Norton, Professor of Mechanical Engineering, Harvard University, Cambridge, Mass.

present moment, concentrated on three major projects, (*a*) viscosity under high pressure, (*b*) journal-bearing performance, and (*c*) oiliness investigations. Results thus far obtained have been published in the Fifth Report of the Committee (17) and elsewhere as indicated above (36–41). The experimental work at the Bureau of Standards is being actively continued on funds of the A.S.M.E. Committee; and will be carefully coordinated with the results of other closely related investigations that are being conducted in cooperation with the Committee by the Bell Telephone Laboratories, General Electric Company, Kingsbury Machine Works, Morgan Construction Company, Pennsylvania State College, Westinghouse Electric and Manufacturing Company, and by the leading American oil refiners.

The investigation of viscosity under high pressure has shown that a complete understanding of the properties of lubricants can only be obtained by considering the absolute viscosity to be a function of both pressure and temperature; and that solidification effects occur with increasing pressures at constant temperature, which may have some important connection with the oiliness, wear-resistance, and seizure characteristics of lubricants. A paper is in preparation on the coordinated results of observations obtained in England, Germany, and the United States on viscosity under pressure.

The effect of "running-in" upon the frictional characteristics of journal bearings has been investigated quantitatively, and charts have been prepared showing the effect of changes in clearance and length upon the friction losses in journal bearings. Pressure distribution in the oil film has been investigated with respect to changes of clearance, change in position of the load, and variations of load, speed, and viscosity of the lubricant.

An experimental investigation of several different types of machines for measuring oiliness and other related properties of lubricants is in progress, including a comparison of the Dickinson, Herschel, Kingsbury, McKee, and Timken machines. The Committee accepts Herschel's definition of oiliness as that property which may cause a difference in the frictional resistance when two oils of equal viscosity at atmospheric pressure, and at the true temperature of the film, are tested under identical conditions. Accordingly, it is considered that the wear-reducing and seizure-preventing characteristics of lubricants must be regarded tentatively as properties that are independent of oiliness; i.e., it cannot be assumed, without experimental proof, that a lubricant possessing greater oiliness than another will necessarily give less wear, or carry heavier loads without seizure.

A beginning has been made on the difficult problem of determining the limiting thickness of film, below which the properties of the lubricant are no longer the same as when tested in bulk. It was concluded that, under the conditions of the present investigation, the ordinary laws of motion of viscous fluids could be relied upon down to films at least as thin as one-millionth of an inch, or 2.5×10^{-6} centimeters (41).

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REDUCING NOISE OF MACHINES

Development of a Soundmeter for the Routine Inspection of Machines Under Factory Conditions

By F. A. FIRESTONE,[1] F. M. DURBIN,[2] and E. J. ABBOTT[3]

WITH the ever-increasing demands for quieter machinery, the problem of noise inspection has become more prominent in the past few years. The unsatisfactoriness of the human ear as a means of holding noise limits is quite generally recognized, and the need for some type of electrical or mechanical sound-indicating instrument to supplement or replace the human ear for inspection is keenly felt in many industrial applications.

A number of noisemeters of various types have been constructed, and several excellent portable instruments for measuring sound pressures are now being placed on the market. Unfortunately, their practical application to the inspection and diagnosis of machinery noises leaves much to be desired. This is no fault of the meters, but is due primarily to the regrettable fact that a reading obtained at a point near a machine usually does not give a satisfactory measure of the noise of the machine.

A soundmeter placed near a machine receives sound simultaneously from the various parts of the machine, and also that reflected from surrounding objects. The sounds arrive at the meter in different phases, so that some positions of the meter can be found where the reading is very small, and others where it is very large. This distribution of sound pressure is called the "wave pattern" or "interference pattern." If the pitch of the sound changes even slightly, the wave patterns shift, and the points of maximum and minimum reading move to new places. If the machine produces two sounds of different pitch simultaneously, each note will have its own wave pattern in the air, and in general the maxima and minima of the two patterns will lie in different places. If the sound consists of a large number of pitches, the large number of resulting wave patterns are superimposed, and the total loudness does not vary so markedly from point to point, though the quality or timbre of the sound may vary greatly.

In every-day life the variations in loudness with position are not very noticeable for several reasons. Among these are the complexity of ordinary sounds, the fact that they are not constant with time so that steady wave patterns are not formed, the use of both ears in listening, and the fact that one pays little attention to them. However, in inspecting machine noises, especially where gear hums or other musical notes are prominent, the loudness variations from point to point are very important, and the effects can be eliminated only by averaging a large number of readings. This is not always feasible in the case of routine inspection, and consequently a soundmeter that gives perfectly correct indications of the physical sound pressures presented to its pick-up may be quite useless for inspection purposes. On the other hand, very satisfactory results have been obtained with meters which have been particularly engineered for the individual application, and which have been designed and built in accordance with preliminary investigations to determine what particular characteristics of the particular noise in question should be measured, and the best means for making these measurements under factory conditions. This article describes such an investigation which was made at The University of Michigan for the purpose of developing a soundmeter for the routine noise inspection of cream separators for the International Harvester Company, which concern supported the project and with whose permission the material is published. While this particular investigation deals with cream separators, the general methods of procedure and many of the problems involved are practically identical with those encountered in a wide variety of machine noises, and it is hoped that what follows will be of interest to those dealing with any type of sound test.

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DETERMINATION OF NOISE CHARACTERISTICS

The first step in any soundmeter application is to determine exactly what sounds are produced, and how they are related to the various moving parts of the machine. For this purpose an analyzing soundmeter whose measurements are independent of any human ear is indispensable. The soundmeter used in this investigation consisted of a microphone, amplifier, tuned analyzer, and indicating meter. By means of the tuned-analyzer circuit it was possible to separate the sound into its component notes, to determine accurately the frequencies of the various notes, and to measure the intensity of each of these components under different conditions.

A group of separators were selected from production and set up in the laboratory. These machines ranged from very quiet to very noisy, the latter being selected to exhibit the various types of noise which had been found to be objectionable. With this arrangement the investigator could pass back and forth from one machine to another to observe differences in the quality of the sound from the different machines, and to correlate the soundmeter readings with aural observations. However, all the final conclusions were drawn from numerical physical measurements taken with the soundmeter.

By continuously varying the tuning of the frequency analyzer over the audible range and observing the indicating meter, it was found that a very large part of the sound produced by these cream separators was concentrated in a few discrete musical notes. The observed frequencies of these notes were compared with the speeds of certain movements in the machine, and it was discovered that each of the notes could be definitely related to a certain part of the mechanism. Thus it appeared that the soundmeter could be used to detect

the sources of the noise as well as to determine whether or not the volume exceeded some assigned limit.

The moving parts of a cream separator consist essentially of a spindle which carries the separating bowl, and which operates at a very high speed, together with a double-reduction gear train by means of which this spindle may be manually operated. If desired, the machine may be driven by an electric motor or other power suitably belted. Table 1 gives the number of teeth and the operating speeds of the various parts of a typical separator.

TABLE 1 FUNDAMENTAL NOTES OF TYPICAL SEPARATOR PARTS

Part	Rpm	No. of teeth	Frequency of fundamental note, cycles per sec.	Name of note
Crank	48	...	0.8	.....
Clutch gear	48	212	169.6	Low-gear note
Pinion	678.6	15		
Intermediate shaft	678.6	...	11.3	.....
Bronze gear	678.6	97	1096.7	High-gear note
Spindle worm	8226	8		
Bowl spindle	8226	...	137.1	Bowl note

The fundamental notes of rotation of the crankshaft and the intermediate shaft lie well below the audible range and thus produce no sound, although the latter might produce vibration which could be felt but not heard. The fundamental note of rotation of the spindle and the tooth-contact frequencies of both gear sets lie within the audible range, and are responsible for most of the noise from these separators. The ball bearing on which the bowl spindle is mounted also produces musical notes which lie within the audible range and whose frequencies can be computed from the dimensions of the bearings. On these particular separators, however, the ball-bearing notes were of comparatively little importance.

Measurements taken with the electrical frequency analyzer showed that not only were all three of the above-listed notes present, but that multiples or harmonics of these fundamental frequencies could also be observed. Accordingly, the noise was found to consist essentially of three series of musical notes whose frequencies were 137.1, 274.2, 411.3, 548.4 .....; 169.6, 339.2, 508.8, 678.4 .....; and 1096.7, 2193.4, 3280.1 ....., respectively. Only the fundamental of the latter series has been measured on the separators of this group, but in the case of the bowl note and the low-gear note, harmonics as high as the fourth or fifth were easily measurable. The relative amounts of these different notes were different for every separator, which furnishes the physical explanation for the difference in the quality of the sound from the individual separators. In this particular investigation it was found that the fundamental note of each of these series was of greater importance than any of the higher harmonics, although this is by no means generally true.

It was found that the intensity of these notes was considerably affected by the load. If the separator was driven at constant speed by means of a motor, one value was obtained; if it was cranked by hand, the intensity would vary with the cranking effort during the various portions of the stroke. A so-called "grunt," which was one of the objectionable noises when hand-cranking, was found to be a sudden change in the intensity of the low-pitch gear note due to the change of load which accompanied the passing of the bottom of the stroke. Since the ear is particularly sensitive to changes in either the quality or the intensity of a sound, these changes were very noticeable. When the machine was allowed to coast without cranking, the other sides of the gear teeth were brought into contact under comparatively light load, and a different noise was produced which was generally less intense than that under usual operation.

Measurements indicated that all of the acoustic energy produced by the separators was not concentrated in the above-described musical notes. Certain of the sounds were of the irregular character technically known as "unpitched sounds," which have no place in the musical scale and which produce the sound called "roughness" by the inspectors. A measure of this unpitched sound can be obtained by subtracting the sum of the analyzed notes of any sound from the "total noise" measurement, or its amount can sometimes be estimated by the readings obtained when the frequency analyzer is set for a frequency at which there is no musical note.

The investigation described above, which was carried out by Mr. L. A. Young, furnished the necessary information concerning the identity of the various noises produced by the separators and their relation to the various parts of the machine. Before designing a meter for routine factory inspection, it was decided to check these findings by measurements on actual production. The laboratory equipment for analyzing and measuring air sounds was taken to the factory and a series of measurements were made on machines in the test booths during the regular aural inspection. These measurements were in good agreement with those obtained in the laboratory. The next step was the development of an instrument for making the measurements rapidly under factory conditions.

DEVELOPMENT OF SPECIAL SOUNDMETER FOR FACTORY USE

A soundmeter for routine factory inspection must meet requirements very different from those of one for use in the laboratory. Simplicity, speed, convenience of operation, ruggedness, and freedom from the effects of extraneous noise and vibration are some of the essentials for a factory instrument which are not so important in the laboratory. In addition, the meter must give a proper inspection of the characteristics of the sound which it is desired to measure, and maintain its calibration over long periods of time. These are rather difficult requirements, and the authors are of the opinion that it will be some time before a general-purpose soundmeter is developed which will answer them for most machine noises. Different applications must be studied and treated individually.

Audio-Frequency Vibration Measurements. The possibility of using a microphone to indicate the intensity of the sound at some point in air near the machine was considered and soon discarded, and the use of audio-frequency vibration was investigated.

It is obvious that the above-mentioned series of musical notes have their origin in mechanical vibrations in the machine which have frequencies that are identical with those of the air sounds. Measurements show that these vibrations permeate the entire machine, and accordingly the audio-frequency vibration at any point on the machine can be analyzed into component frequencies exactly as can the sound at any point in air.

A group of tuned vibration pick-ups was constructed for measuring the different notes on the cream separators. Each of these consisted of a reed, tuned to the desired frequency, which was clamped to an appropriate part of the machine, and whose amplitude of vibration was measured by means of the voltage generated in a small magnetic coil placed close to the reed.

Measurements were made to determine the relative noise ratings of a group of five selected separators. This was done by measuring the analyzed vibrations at six corresponding positions on each machine and taking the average. The locations of these positions were as follows: (1) Side of bowl

housing; (2) above drip shelf on side opposite crank; (3) on horizontal surface above crankshaft; (4) top of large gear housing; (5) center of large gear housing opposite crank; and (6) above drip shelf, on same side as crank. The averages of the results of these measurements are shown in Fig. 1.

Separator No. 1 had been passed by the factory inspectors as satisfactory for noise, and each of the others had been rejected. Accordingly, the values for each note of separator No. 1 have arbitrarily been called "zero," and the other machines rated with respect to this one. A negative value represents a quieter sound than that of separator No. 1, and a positive value a louder one. The unit of comparison is the decibel (db), which corresponds to about a 12 per cent change in sound pressure. For practical purposes one decibel represents about the smallest change of loudness that is perceptible to the average human ear. Thus, if two machines differ by 5 db, one of them would have to be changed five times by a just perceptible amount each time to make their loudnesses equal. The total would be a very noticeable change. For comparison, if the application of acoustic treatment to an office or similar room reduces the room noise by 5 or 6 db, the improvement is very marked.

From the data of Fig. 1 it is readily apparent why separator No. 1 was much quieter than the others, and also what particular part of the mechanism was responsible for the rejection of each of the other machines. Separator No. 1 showed either the smallest or the next to the smallest reading of any of the five separators for each of the three most important notes: the bowl-spindle note, the low-gear note, and the high-gear note. In each case it was exceeded in loudness by one or more of the other machines by 10 to 15 db. This amount is comparable with the reduction in sound through a $1^3/_4$-in. solid oak door with cracks as ordinarily hung. From these data it appears that separator No. 2 had very quiet high gears, but had been rejected for bowl-spindle note and low-gear note. Separator No. 3 was slightly the quietest of the group for bowl-spindle and low-gear notes, but had been rejected for its high-gear note. Separator No. 4 showed fairly large amounts of all three notes, while separator No. 5 showed large bowl and high-gear notes, and a moderate amount of low-gear note.

Measurements on the second harmonic of the bowl-spindle note bore little relation to those of the fundamental bowl-spindle note. Separator No. 3 was the quietest in both cases, but separator No. 5, which had the largest fundamental, showed next to the smallest second harmonic. This is evidence that the relative importance of a group of harmonics is liable to vary greatly from machine to machine.

Unfortunately the data of the different frequencies in Fig. 1 have no common basis of comparison; that is, no conclusions can be drawn as to the relative loudness of the four notes on any one machine. It is obvious that the average sound pressure in the air around a machine cannot be computed from the amplitude of vibration of any particular part of the machine, because the average sound pressure is affected by the sizes and the amplitudes of vibration of the many sound-emitting surfaces of the machine. For this reason vibration measurements are valuable for purposes of comparison on similar machines, but do not furnish absolute loudness indications, even though the actual vibration amplitudes are known in units such as the millionth of an inch. On this account it did not seem worth while to determine the absolute calibration of the vibration microphones at the various frequencies. The procedure which was followed was to obtain the proper relative ratings for each note on the various machines, and to set a separate limit for each note on the basis of tests on separators under routine conditions at the factory.

Microphone Location. The above-described measurements gave a very satisfactory noise rating for each separator, but the procedure was altogether too cumbersome for factory use. The next step was to determine if proper relative ratings could be obtained by means of analyzed vibration measurements at a single point on each machine. Fig. 2 shows a group of measurements which were made to test this point. The "zero" of the decibel scale is taken as the average value of the note in question for machine No. 1. Straight lines are drawn between the various readings for each machine, and the rise and fall of these lines across the graph indicates the variation in vibration from point to point on the machine. These variations on each machine were of the order of 20 db, which corresponds to a factor of 10 to 1 in the vibration amplitude. In certain soundmeter applications these variations are so great that satisfactory inspection at a single microphone location is

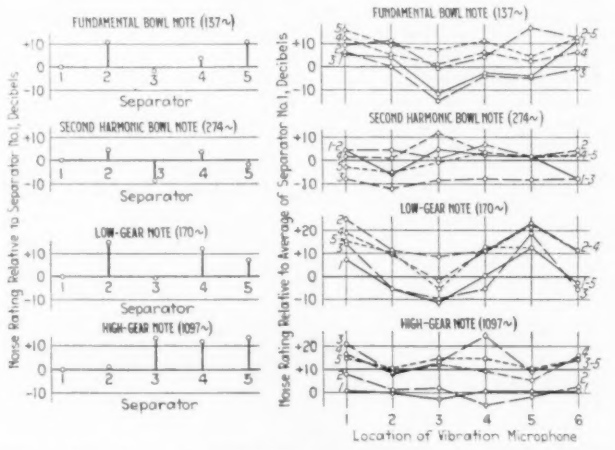

FIG. 1 (LEFT) NOISE RATINGS OF FIVE SEPARATORS RELATIVE TO SEPARATOR NO. 1

FIG. 2 (RIGHT) VARIATION OF NOISE RATING WITH LOCATION OF VIBRATION MICROPHONE

impossible, but in the present case they were not so serious.

It was found that measurements at position 1 placed the five machines in very nearly the same order as did the average reading. For each of the three important notes, separator No. 1 measured the quietest, and the machines which were materially louder with respect to the note in question showed considerably larger readings. Therefore it was concluded that satisfactory inspection could probably be obtained by measurements at position 1. This position was also favored on account of its accessibility, its importance as an integral part of the frame, and the fact that greater indications were obtained than at any of the other positions.

Test of Method. The method of inspection finally adopted for the cream separators under investigation was the separate measurement of the bowl-spindle note, the low-gear note, and the high-gear note. These measurements were obtained by means of three vibration microphones mounted at position 1, each microphone being tuned to measure one of the required notes. Before the apparatus was installed in final form in the factory, a number of measurements were made at the laboratory and at the factory to check the accuracy of the method.

Tolerance limits in terms of instrument readings were determined for each of the three notes by measurements on a group of quiet and noisy separators, and following this the instrument was used for inspection and diagnosis along with the regular inspection. The results were very successful.

It had been found by laboratory studies that fairly satisfactory indications of the "roughness" or "unpitched sound" were obtained by using a pick-up tuned to a frequency at which no musical note existed. This was checked by measurements at the factory, and it was found that practically no machines showed "roughness" unless one of the three principal notes was also large. Accordingly, it was decided to inspect by instrument for the three important notes, and to depend on the inspector to catch unusual sounds such as a single defective tooth, unusual roughness, or similar peculiarities. This

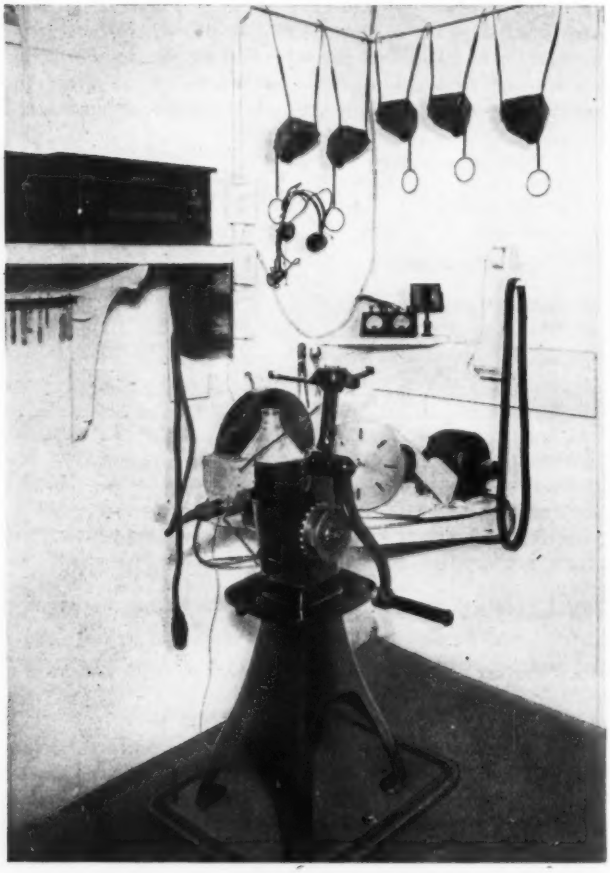

FIG. 3 INTERIOR OF TESTING BOOTH, SHOWING SEPARATOR AND SOUND-MEASURING APPARATUS

simplified the apparatus and speeded the inspection considerably without particularly affecting the accuracy.

The Factory Installation. The details of the final installation were considerably affected by the layout of the testing and inspecting operations. Ordinarily two different sizes of separator are manufactured simultaneously, so that it is often desired to test first one and then the other. For this reason the booth shown in Fig. 3 was equipped with two complete and separate sound-measuring outfits, each of which is normally set up for a different size of machine. Each unit consists of a small box containing vibration microphones, a selector switch, an amplifier, and an indicator meter. The microphone box is mounted on the side of the bowl casing (position 1) and held by means of springs as shown. It contains the three vibration microphones which are tuned respectively to the bowl-spindle note, the high-gear note, and the low-gear note of the separator under test. A flexible "plug-in" cable connects the microphone box to the selector switch on the wall, and by means of this switch each of the microphones can be connected in turn to the amplifier, which is in the box on the shelf to the left of the picture. The indicator meter is mounted on the small shelf shown in the center of the picture in a convenient position for the operator to observe.

In order to bring out the desired notes it is necessary to operate the separator by hand, and at the same time it is essential to maintain very constant speed so that the analyzing microphones will be in tune with the desired notes. The speed indicator on the separator is not quite accurate enough for this purpose, so a stroboscopic means has been provided. A small lamp is mounted behind the slotted disk shown just behind the separator handle. This disk is driven by a small synchronous motor, and the light passing through the slits falls upon the pulley just below the handle. The alternate white and black stripes on the pulley are so arranged that they appear to stand still when the separator is turned at the proper speed. The operator can view the stripes by means of the small mirror mounted beside the indicator meters.

One inspector passes upon the machines in all of the three test booths, the time while he is in the other booths being used by his assistant in changing separators and bringing the new ones up to speed. From this it is clear that the soundmeter is in use in only one booth at a time. It was only necessary, therefore, to duplicate the selector switches and the indicator meters in all three booths and to use the same pair of amplifiers throughout. This arrangement not only simplifies the installation, but insures identical limits in all three booths because the same apparatus is used.

The primary calibration is made against a group of selected separators and is carried out as follows: The standard machine of the proper type is carefully warmed up and installed in the booth. The selector switch is set for one of the notes and the indicator dial reading is observed. If the reading does not come to the passing limit as indicated by the red line at the center of the dial, the proper volume control on the amplifier is adjusted until it does so. The vibration microphone box is then removed from the machine, and a 60-cycle voltage is introduced into the amplifier by turning the "calibrating voltage" dial. This is adjusted until the indicator reads at the red line, and the reading of the calibrating dial is recorded. This is repeated for each of the three notes.

Secondary calibrations are then made by setting the calibrating dial to the proper setting, and adjusting the volume control until the indicator reads at the red line. This is repeated for each note, a process which occupies but a few seconds. Occasional primary calibrations against the standard separators show that the microphone sensitivity is essentially constant, and that secondary calibrations are sufficient for ordinary operation.

CONCLUSION

The apparatus described was installed in the Milwaukee plant of The International Harvester Company in the spring of 1928, has been in continuous use since that time, and only minor repairs and adjustments have been necessary.

The results of this instrumental inspection have been even more satisfactory than had been anticipated. Each separator built has been inspected with the apparatus described, and with the elimination of the human element the inspection has been more uniform and consistent, and the diagnosis of faulty parts more positive. These have resulted in a more uniform product, and complaints of noise from the field have approached the vanishing point.

The Basic Laws and Data of HEAT TRANSMISSION[1]

By W. J. KING[2]

II—CONDUCTION

THE majority of heat-conduction problems occurring commonly in engineering practice involve only the steady flow of heat through bodies of simple shapes, such as flat walls, bars, and cylinders. The mathematics involved in more complex cases are usually common to all types of flow problems, and may frequently be derived by analogy from analyses of the flow of electricity or of fluids. For example, the transient flow of heat through a metal rod has much in common with the charging of a telegraph cable. It is merely necessary to substitute thermal potential (temperature), heat capacity, and resistance for the corresponding electrical terms.[3]

The subject of conduction will therefore be treated here from the thermal rather than the mathematical point of view. The principal concern will be with the conductivities of various classes of materials, from which the heat flow may be calculated for the typical case by substituting in the equation

$$q = \frac{kA(t_1 - t_2)}{L} \quad \ldots\ldots\ldots\ldots\ldots\ldots [1]$$

This equation expresses the fundamental law of heat conduction, which says that the rate of heat flow is directly proportional to the conductivity, the area, and the temperature difference, and inversely proportional to the length of the path.

Equation [1] applies only to the simplest case, where the heat flows through a single path of constant cross-section. For a number of industrially important cases it is necessary to substitute the average area, when the cross-section is not constant, or to compute the overall transmission, where the heat flows through several paths in series or in parallel. For example, when the heat flows radially between two concentric cylinders, as in the insulating lagging of a steam pipe, the area increases with the radius, and the average is

$$A_{avg} = \frac{A_2 - A_1}{\log_e\left(\frac{A_2}{A_1}\right)} = \frac{A_2 - A_1}{2.3 \log_{10}\left(\frac{A_2}{A_1}\right)} \quad \ldots\ldots\ldots [2]$$

This is known as the logarithmic mean area, and should be used whenever the ratio of the outer and inner areas is considerably greater than 2, instead of the simple arithmetical average, $(A_2 + A_1)/2$.

Expressions for some further useful shapes have been derived by Langmuir, Adams, and Meikle,[4] and C. W. Rice[5] has described an experimental method for obtaining the solution of any flow problem.

For computing the overall flow through combinations of paths, it is necessary merely to remember that kA/L is the thermal conductance of a specific path, the reciprocal of which is the resistance, and that conductances are directly additive in parallel, while resistances are additive in series flow.

UNITS

In engineering practice the heat flow is usually expressed in British thermal units per hour, the area in square feet, the temperature in degrees fahrenheit, and the length or thickness in inches, so that the conductivity is written as Btu/hr/sq ft/F/in. This convention will be adopted for the present purpose, because most engineers are accustomed to thinking in such terms, and because it gives a better idea of the actual magnitude of the heat flow as compared with other processes under ordinary conditions. It should be clearly understood, however, that this is a matter of convenience and custom, and that wherever the conductivity is used in more general mathematical operations it should be expressed in consistent units, such as Btu/hr/sq ft/F/ft, in which a single unit of dimension is used for both area and length. There appears to be no hope of standardizing on a single unit, as each one seems to be firmly established for its particular purpose.

The following factors are given for converting the data in this article to other common units:

k = Btu/hr/sq ft/F/in.

Divide k by $\begin{cases} 12.0 \\ 8.064 \\ 694.0 \\ 2903.0 \end{cases}$ to get $\begin{cases} \text{Btu/hr/sq ft/F/ft} \\ \text{Kg-cal/hr/sq m/C/m} \\ \text{Watt/sq cm/C/cm} \\ \text{Cal/sec/sq cm/C/cm} \end{cases}$

METALS AND ALLOYS

The conduction of heat through pure metals and alloys is apparently effected by two processes: (1) the passage of free electrons through the lattice of the molecules, and (2) the vibration of the molecular system, sometimes called the "dielectric component." The first effect predominates to such an extent as to suggest an analogy between the flow of heat and electricity. In fact, it has been found[6] that the ratio of the thermal to the electrical conductivity at a given temperature is practically constant for the pure metals, and reasonably so for most alloys. This provides a convenient criterion of the thermal conductivity, when the electrical conductivity or specific resistance is known. In engineering units this relation is expressed by

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[1] Part I, a general survey of the subject, appeared in the March issue, pp. 190–194.

[2] Engineering General Department, General Electric Company, Schenectady, N. Y.

[3] See "The Mathematical Theory of Heat Conduction, With Engineering and Geological Applications," L. R. Ingersoll and O. J. Zobel, Ginn & Co., 1913; "Introduction to the Mathematical Theory of the Conduction of Heat in Solids," 2d Ed., H. S. Carslaw, Macmillan & Co., Ltd., London, 1921.

[4] Langmuir, Adams, and Meikle. Trans. Am. Electrochem. Soc., vol. 24 (1912), p. 53.

[5] C. W. Rice. Trans. A.I.E.E., vol. 36 (1917), p. 905.

[6] E. Griffiths and F. H. Schofield. *Jl. Inst. Metals*, vol. 39 (1928), p. 337. W. Mannchen. *Zeit. für Metallkunde*, vol. 23 (1931), no. 7, p. 193.

$$\frac{k\omega}{T} = 58$$

where k = Btu/hr/sq ft/F/in.
ω = ohms per circular-mil-foot
T = deg F absolute.

This is an average figure, which usually runs a little lower for the pure metals and little higher for alloys. It does not apply at all for other classes of materials.

The conductivities of some technically important metals are given in Table 1, for a temperature of 68 F (20 C).

TABLE 1 CONDUCTIVITIES OF CERTAIN TECHNICALLY IMPORTANT METALS AT 68 F

	k
Aluminum	1460
Bearing metal (white)	164
Brass (70 Cu:30 Zn)	770
Constantan (60 Cu:40 Ni)	162
Copper	2665
Gold	2050
Iron, wrought	420
Iron, cast, gray	350
Lead	241
Mercury	57
Monel metal (70 Ni:28 Cu:2 Fe)	241
Nichrome (62 Ni:12 Cr:26 Fe)	94
Nickel	405
Platinum	483
Silver	2840
Steel (1% C)	300
Tin	440
Tungsten	1110
Zinc	770

For pure metals the conductivity decreases slightly with increasing temperature, with the exception of aluminum, for which k increases appreciably at higher temperatures. (See Fig. 1.) For most non-ferrous alloys the conductivity increases considerably with the temperature. (See Fig. 2.) The increase in k for brass from 770 at 68 F to 1010 at 400 F is representative of the amount of variation to be expected. On the other hand, the conductivity of gray cast iron drops from 350 to 220 in the same temperature range.

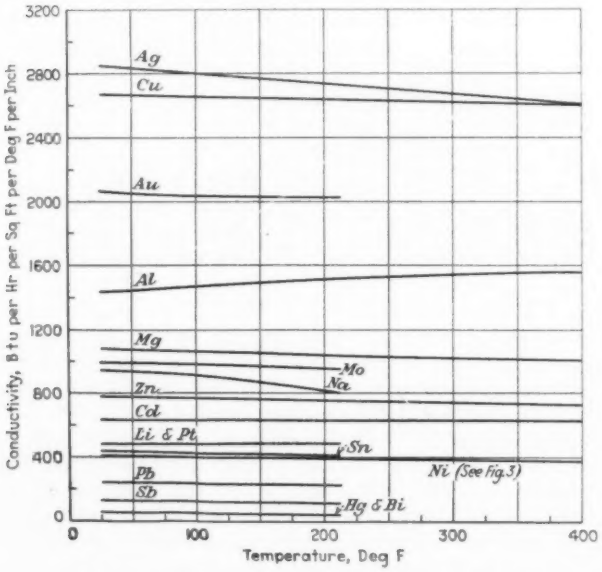

FIG. 1 THERMAL CONDUCTIVITIES OF PURE METALS

In general, alloys have lower conductivities than the pure metals. The addition of a small amount of another metal will sometimes result in a sharp drop in the conductivity of a pure metal, particularly when a solid solution is formed. For example, for an alloy of 10 per cent tin and 90 per cent silver, the conductivity k is only 7.3 per cent of that for pure silver.[7] The presence of other metals or impurities in copper usually has a very marked effect. A little arsenic or phosphorus may reduce the conductivity of copper to the point where it is no better than steel as a conductor of heat.[8] For this reason any copper that is used in heat-transfer equipment because of its thermal properties, such as for extended heating surfaces, should be tested for its purity, and the simplest way is to compare its electrical resistance with that of a similar specimen of standard electrical copper.

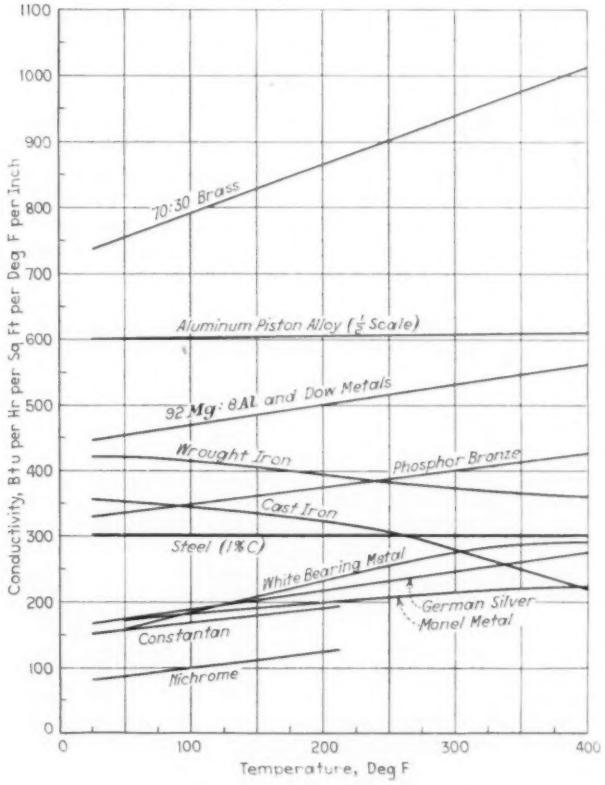

FIG. 2 THERMAL CONDUCTIVITIES OF CERTAIN ALLOYS AND FERROUS METALS

(The curve for Aluminum Piston Alloy is typical of a large group of alloys containing from 4 to 12 per cent of copper and small amounts of nickel, iron, and manganese. See footnote 6.)

Practically all of the alloy steels have lower conductivities than wrought iron. When the added constituents (C, Co, Cr, Mn, Mo, Ni, Si, V, W, etc.) are present in small percentages, the value of k is usually about 280, with lower values (k = 125 for 25 per cent chromium stainless steel and 72 for Invar) as the percentage is increased.

The thermal conductivity of metals is dependent upon the grain structure, and hence upon the type of heat treatment. The effect of heat treating is generally slight in the pure metals, but is more pronounced in the alloys, particularly the

[7] A. W. Smith. "The Thermal Conductivities of Alloys," Ohio State Univ. Eng. Exper. Sta. Bull. no. 31, 1925.

[8] C. S. Smith. "Thermal Conductivity of Copper Alloys." A.I.M.E. Tech. Pub. no. 360, 1930.

steels. In the latter, annealing increases the conductivity, while quenching usually lowers it by a considerable amount.

The variation in the data reported in the literature for some of the important metals is brought out graphically by the curves of Fig. 3, for nickel. While the agreement for most other metals is better, this typifies the kind of data which are frequently encountered in thermal work, as well as the need for more reliable methods and the occasion for a critical survey of all available information before accepting any one set of data.

HEAT-INSULATING MATERIALS

There are an enormous number of thermal insulators now on the market, and new ones are constantly being submitted.

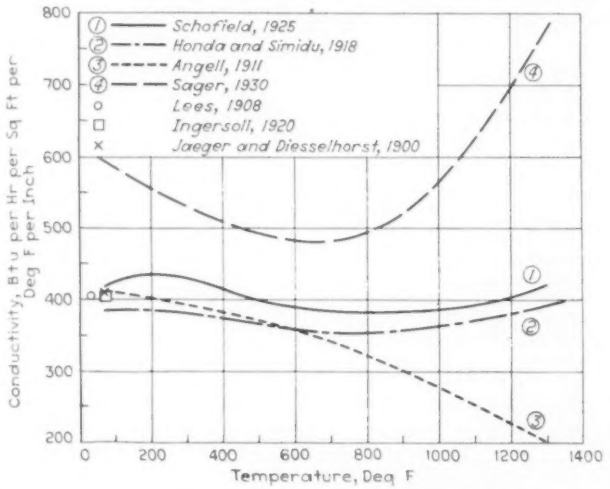

FIG. 3 THERMAL CONDUCTIVITY OF PURE NICKEL

In developing or selecting any such material, the following features should be considered: (1) low conductivity; (2) low cost; (3) low density; (4) low thermal capacity; (5) ease of application; (6) mechanical strength; (7) durability (slow aging); and its (8) vermin-proof, (9) non-rusting, (10) fireproof (heat-resisting), (11) non-hygroscopic or moisture-proof, and (12) non-odorous properties. The significance of each factor depends, of course, upon the particular application for which it is intended.

With regard to the conductivity, it is possible to make some generalizations.

1 The conductivities of all homogeneous solid materials are relatively high; practically all good insulators are porous, cellular, fibrous, or laminated materials.

2 In general, the conductivity increases with the density and the elasticity.

3 With rare exceptions, the conductivity of insulating materials increases very considerably with the temperature.

4 The absorption of moisture greatly impairs the insulating value of porous materials.

5 The conductivity of a powdered or porous substance may be varied considerably above or below its normal value in air by substituting hydrogen, carbon dioxide, or some other gas for the air. For finely powdered substances the value of k may be lowered very rapidly by reducing the air or gas pressure.

Heat is transmitted through a homogeneous opaque substance by pure conduction, but in very porous materials radiation is frequently an important factor as a parallel process, and if the pores are large enough, convection currents may help to carry the heat. While an appreciation of the relative significance of these factors is very helpful in clarifying the mechanism of heat transfer through insulating materials,[9] they are not considered separately in expressing the ordinary conductivity of porous materials, which includes the combined effect, or the total equivalent conductivity of all processes. It should be clearly understood, however, that this is the *internal* conductivity and does not include external surface coefficients, which must be taken into account when computing the overall transmission, U, as from air to air across an insulating wall.

Some representative values for low-temperature insulation are given in Table 2.

TABLE 2 CONDUCTIVITIES OF CERTAIN LOW-TEMPERATURE INSULATING MATERIALS

	Density (lb per cu ft)	k (at 90 F)
Aluminum foil[a]	0.2	0.29
Balsa wood	8.8	0.38
Balsam wool	2.2	0.27
Celotex	13.2	0.34
Corkboard	10.6	0.30
Dry Zero	1.0	0.25
Hair felt	11.0	0.26
Insulite	16.9	0.34
Rock wool	10.0	0.27
Paper, corrugated	3.5	0.27

[a] With 3 air spaces per inch.

These figures vary considerably with the amount of binder, waterproofing, compression, and other structural features, so that the references given[10] should be consulted for more specific information.

In the field of moderate- and high-temperature insulation, the works of Heilman[11] and McMillan[12] are outstanding. Some of their results are included in Fig. 4. These are average values; the figures for the same type of material made by different manufacturers are apt to vary somewhat.

ELECTRICAL INSULATING MATERIALS

The most complete work on this class of materials is reported in a paper on "The Thermal Resistivity of Solid Dielectrics," published by the British Electrical and Allied Industries Research Association, in the *I.E.E. Journal*, Vol. 68, October, 1930, page 1313. The papers by Taylor[13] and Randolph[14] also contain valuable information.

For many applications it is desirable to have a material which is a good electrical insulator, but with a relatively high thermal conductivity. Pure mica, porcelain, and glass are outstanding materials in this respect.

Unfortunately, most electrical insulations are applied in built-up or laminar form. The poor thermal contact between layers, or the admixture of binding materials, such as paper and shellac in mica tape, lowers the heat conductivity very considerably and results in wide variations in the data reported, depending upon the construction and treatment. The conductivity of laminated insulation may sometimes be doubled

[9] See R. H. Heilman. MECHANICAL ENGINEERING, vol. 52 (1930), p. 693. W. J. King. *Refrig. Eng.*, vol. 20 (1930), p. 169.

[10] "Heat Transmission of Insulating Materials." Circular No. 1, Am. Soc. Refrig. Engrs., 1924. "Mechanical Equipment of Buildings." L. A. Harding and A. C. Willard. 2nd Ed., vol. 1, John Wiley and Sons, N. Y., 1929.

[11] R. H. Heilman. MECHANICAL ENGINEERING, vol. 46 (1924), p. 593; vol. 48 (1926), p. 1297. *Chem. Met. Eng.*, vol. 38, p. 390, July, 1931.

[12] L. B. McMillan. Trans. A.S.M.E., vol. 37 (1915), p. 921; vol. 48 (1926), p. 1269.

[13] T. S. Taylor. *Elec. Jl.*, vol. 16 (1919), p. 526.

[14] C. P. Randolph. *Gen. Elec. Rev.*, vol. 16 (1913), p. 120.

by increasing the pressure, or by impregnating with varnish or an asphaltic compound.

The conductivity generally increases with the temperature about as shown for the materials of Fig. 4. The figures in Table 3 are average values for a temperature of 100 F.

In electrical design it is customary to use, instead of k, the thermal resistivity, R, in deg C/watt/cu in., which may be obtained from the expression

$$R = \frac{273}{k}$$

MISCELLANEOUS SOLID AND POROUS MATERIALS

Under this heading it is impossible to give more than a few representative conductivities for some of the materials com-

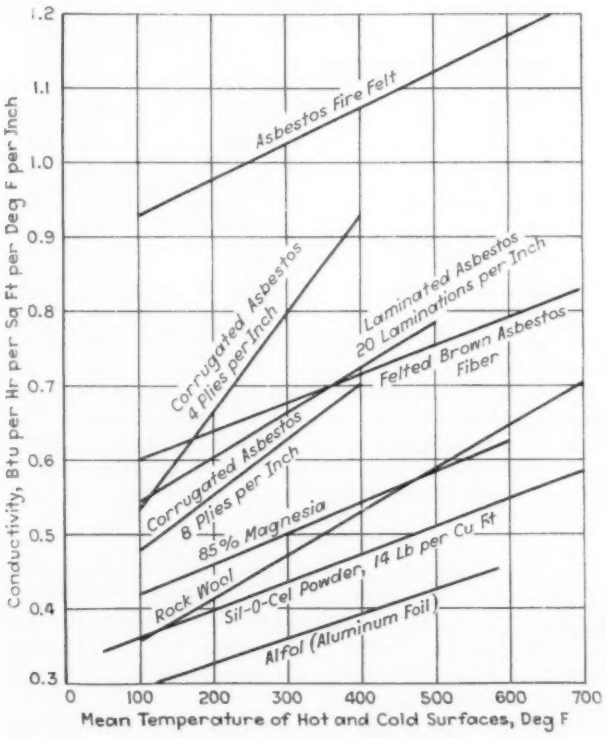

FIG. 4 CONDUCTIVITIES OF HEAT-INSULATING MATERIALS

monly encountered in practice. For data on building materials the "Guide" published annually by the American Society of Heating and Ventilating Engineers, or the A.S.R E. data book,[10] should be consulted. Professor Trinks's text on "Industrial Furnaces"[15] contains a collection of data on refractories. An excellent discussion of the conduction of heat through powders and its dependence on the pressure and conductivity of the gaseous phase, will be found in a paper by Aberdeen and Laby in the Proceedings of the Royal Society, Vol. 113 (1926), page 459.

In many practical problems the exact description of the material to be used is not known, and frequently all that is desired is an idea of the normal range over which the conductivity may be expected to vary. The data in Table 4 are given for this purpose, the temperature in each case being that at which the material is normally used.

TABLE 3 THERMAL CONDUCTIVITIES OF ELECTRICAL INSULATING MATERIALS

(Average values for a temperature of 100 F)

	k
Cambric, varnished	1.10
Cotton tape, untreated	0.52
Ebonite	1.15
Fiber, sheet	2.00
Glass, plate	5.50
Mica, sheet	3.85
Micafolium	1.20
Micanite, commutator	2.80
Paper, board, varnished	2.00
Paper, Kraft tissue	0.27
Porcelain	10.00
Pressboard	1.25
Silk, varnished	1.15
Silk, untreated	0.32

TABLE 4 CONDUCTIVITIES OF VARIOUS INDUSTRIAL MATERIALS

(At temperatures of normal use)

	k
Boiler scale	1.2 –60.0
Brick, building	1.5 – 5.0
Brick, refractory	4.0 –15.0
Concrete	5.0 –15.0
Cotton	0.2 – 0.5
Earth	1.0 – 4.5
Glass	4.2 – 5.8
Ice (32 F)	14.6 –15.6
Rubber, solid	1.0 – 1.5
Rubber, sponge	0.3 – 0.4
Sand	2.0 – 8.0
Slate, across grain	8.8 –10.4
Wood, across grain	0.7 – 1.4
Wool	0.16– 0.26

The extreme range in the data reported for boiler scale is due to variations in composition, porosity, and crystal structure. The lowest values were found for amorphous, highly porous deposits, and the highest for large, dense crystals. The higher figures for the other materials composed of mineral matter correspond to the higher densities and moisture contents. The conductivity of ice increases at lower temperatures to a value of 28 at −200 F. The value of k for wood increases with the density and gum content; the range given in the table extends from white pine at the lower to heavy oak at the upper limit. The conductivity of wood and slate along the grain is always roughly double that across the grain. Loose cotton, wool, and flax fibers show a marked decrease in conductivity as the density is increased by compression from about 1 to 10 lb per cu ft, due probably to a reduction in the internal radiation and air movement between the fibers. Many fibrous materials, such as jute, bagasse, straw, cornstalks, and wood pulps, show a minimum conductivity (at 90 F) of about 0.28 at a density of 5 lb per cu ft.

LIQUIDS

Although several attempts have been made[16] to connect the thermal conductivity with other properties of liquids, no simple and useful relationship has been found. For practical purposes, the simple formulas are unreliable, and the accurate ones are too complicated. However, the outstanding facts with regard to liquids are these: The conductivities of most organic liquids are grouped fairly closely around an average value of $k = 1.0$ at 68 F, and decrease rather slowly at higher temperatures. Water (see Fig. 5) and glycerine are unique in that their conductivities are several times higher (4.1 and 1.98, respectively), and increase considerably with the temperature. Very few data are available for other inorganic

[15] Published by John Wiley and Sons, N. Y., 1926. 2nd Ed., vol. I, p. 65.

[16] J. F. Downie-Smith. *Ind. Eng. Chem.*, vol. 22 (1930), p. 1246; vol. 23 (1931), p. 416.

liquids, although high values are also reported for ammonia and sulphur dioxide. The conductivity of aqueous solutions is generally lower than that of water by an amount roughly proportional to the concentration of the solute. The effect of pressure is generally negligible, although at extremely high pressures the conductivities of most liquids may be more than doubled.[17]

Lees[18] has given several formulas for the conductivity of binary liquid mixtures. None is exact, but for practical purposes the simple relation

$$k = \frac{p_1 k_1 + p_2 k_2}{p_1 + p_2}$$

may be used, where p_1 and p_2 are the parts of each component by volume.

Table 5 gives the conductivities of some technically important liquids at 68 F, together with the temperature coefficient, a, as defined by the equation

$$k_t = k_{68}[1 + a(t - 68)]$$

where k_t is the conductivity at any temperature between 32 and 200 F.

GASES

According to the kinetic theory,[19] the thermal conductivity of an ideal gas is proportional to the product of its viscosity and its specific heat at constant volume:

$$k = \epsilon \mu c_v$$

For real gases this relation has been found to hold fairly well, although the constant ϵ depends upon the number of atoms in the molecule, as shown below.

	ϵ C.g.s. units	ϵ Eng. units[a]
Monatomic gases	2.45	106,000
Diatomic gases	1.90	82,000
Triatomic gases	1.70	73,500
Complex gases[20]	1.30	56,000

[a] Engineering Units: k in Btu per hr per sq ft per deg F per inch; μ in lb per ft-sec.

The author has tested these values of ϵ in the above equation for about thirty gases for which fairly reliable data are available. The agreement was generally within the limits of the experimental accuracy of the data. Due to the necessity for eliminating radiation and convection,[21] the conductivity of a gas is more difficult to measure accurately than the viscosity and specific heat. For this reason it might be worth while to establish the exact values of ϵ more definitely, to further verify the reliability of this method of calculating k.

Theoretically the conductivity of a gas should be proportional to the square root of its absolute temperature. As a rough generalization, this has been borne out by the experimental data, although it is usually the practice to express the

[17] "Physics of High Pressure," P. W. Bridgman. Macmillan Co., N. Y., 1931.

[18] C. H. Lees. *Phil. Mag.*, vol. 49 (1900), p. 286.

[19] "Kinetic Theory of Gases," L. B. Loeb. McGraw-Hill, N. Y., 1927. "The Dynamical Theory of Gases," J. H. Jeans. Cambridge Univ. Press, 1925.

[20] Theoretically the value of ϵ should approach 1.0, in c.g.s. units, as the lower limiting value for gases of high molecular weight. See "Handbuch der Experimentalphysik" (Wien and Harms), vol. 9, p. 261.

[21] See "Experimental Determination of the Thermal Conductivities of Gases." H. Gregory and C. T. Archer. Proc. Roy. Soc., vol. 110, p. 91, January, 1926.

TABLE 5 CONDUCTIVITIES OF VARIOUS TECHNICALLY IMPORTANT LIQUIDS AT 68 F

	k_{68}	a
Acetone	1.24	−0.00074
Ammonia	4.03	.....
Benzene	1.18	.....
Carbon bisulphide	1.11	−0.00065
Carbon dioxide	1.45	.....
Carbon tetrachloride	0.76	.....
Ether	0.95	−0.00026
Ethyl alcohol	1.26	−0.00039
Glycerine	1.98	+0.00029
Kerosene	1.05	−0.00081
Methyl alcohol	1.44	−0.00029
Oil, lubricating	1.16	−0.00023
Oil, transil*	0.93	−0.00034
Pentane (normal)	0.94	−0.00057
Sulphur dioxide	2.34	.....
Turpentine	0.88	.....
Toluene	1.05	−0.00080
Vaseline	1.27	.....
Water	4.10	+0.0010

* In the first article of this series, on page 194 of the March issue, under "Representative Coefficients," the conduction through $^1/_{16}$ in. of oil should read 15.0 instead of 1.50.

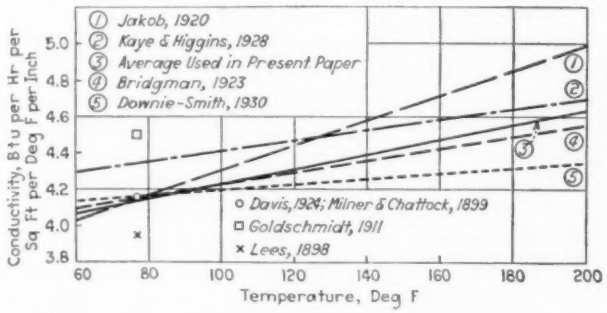

FIG. 5 THERMAL CONDUCTIVITY OF WATER ACCORDING TO VARIOUS OBSERVERS

variation of the conductivity with the temperature by means of the Sutherland equation:

$$k_T = k_{492}\left(\frac{492 + C}{T + C}\right)\left(\frac{T}{492}\right)^{3/2}$$

where T is the temperature in degrees fahrenheit absolute, and C is a constant depending upon the gas. The conductivity is sometimes expressed as a linear function of the temperature:

$$k_t = k_{32}\,[1 + a\,(t - 32)]$$

which is sufficiently accurate over moderate ranges of t.

The values given in Table 6 were selected by the author after a critical survey of the published data. The lack of agreement among even the most competent and careful investigators[22] is such that the accuracy is probably not better than ±5 per cent in most cases. The conductivities are for a temperature of 32 F, or 492 deg absolute.

Both theory and experiment indicate that the conductivity of a gas is independent of the pressure, except at very low or high pressures. When the pressure is reduced to the point where the mean free path of the gas molecules is of the same order of magnitude as the length of the heat path, the conductivity becomes proportional to the pressure.[23]

(*Continued on page 296*)

[22] A survey of the methods and data for air, H_2, and CO_2, with a bibliography of 204 references, is given in a paper by Trautz and Zundel, in *Zeitschrift für technische Physik*, vol. 12 (1931), no. 6, p. 273.

[23] See J. Aberdeen and T. H. Laby, Proc. Roy. Soc., vol. 113 (1926), p. 459; A. Trowbridge, *Phys. Rev.*, vol. 2 (1913), p. 58; "Handbuch der Experimentalphysik" (Wien-Harms), vol. 9 (1929), part 1, p. 261.

MECHANICAL ENGINEERING

Vol. 54 APRIL, 1932 No. 4

GEORGE A. STETSON, *Editor*

F. L. Hutchinson

ONE of the most practical advantages that come from the common headquarters of the engineering societies in the Engineering Societies Building in New York is the opportunity it affords for the close cooperation of the national secretaries in matters of mutual interest, not only to the great groups of engineers each of them represents, but to the secretaries themselves. A combined wisdom is available to assist individual judgments.

From this small but important group, F. L. Hutchinson, secretary of the American Institute of Electrical Engineers, was separated by death on February 26, 1932. His long experience with the Institute, which commenced in 1904 and resulted in his appointment as national secretary in 1912, gave weight to his influence in inter-society affairs. The services he rendered the Institute are visible in its present status and in its dignity and importance in the engineering profession. The services he rendered to the engineering profession, and to the A.S.M.E. in particular, are no less real if they are less obvious. The engineering societies have lost an exemplary national secretary and a valued counselor.

Impotent Business

WITH such a title, George Soule, in *The New Republic*, presents the first of a series of articles adapted from his forthcoming book, "A Planned Society." In this article he calls "the roster of those who, in different capacities, are sometimes believed to have powers to manage our civilization." Naturally, along with the small business man, the citizen, the industrial executive, the banker, and the consumer, the engineer is examined, and found wanting.

At the present time no one is likely to quarrel with Mr. Soule, lest by so doing he accept a responsibility for the overwhelming burder of disasters that afflict us today. This Mr. Soule points out. And he shows that the impotence to control, realized by all these groups, has led them to think of society as something apart from themselves and to seek refuge from it.

We have frequently exhorted engineers not to persist in this state of isolation, and have given opportunity to many who would urge their fellows away from it to publish their thoughts on the subject.

We are all in the boat together. Whatever the way out may be, it would seem to depend upon cooperation of the groups, and not a domination of them all by one. Last month Mr. Hirshfeld showed how scientific research might help. Elsewhere in this issue Mr. Flanders points to an increased cooperation between engineers and bankers.

Don't Neglect Education!

IN AN ECONOMIC crisis, education is likely to suffer with other important elements of civilized communities. Development programs are held up, salaries and wages are threatened, faculties reduced, researches interrupted, and ambitious and worthy young folk are deprived of the experience of college life. Prominent persons, including President Hoover, recognize the potential dangers to our national life that are incident with a slowing down of the educational machine, and warn against them. President Davis, of Stevens Institute, who some time ago made the suggestion that increasing the physical equipment of educational institutions in times of depression would not only be of lasting benefit in providing improved and much-needed facilities, but also of material assistance locally in providing work for some unemployed, proposed in an address to the Stevens alumni an emergency relief corporation for colleges that would make loans and other funds available in the present emergency so that investment portfolios need not be sold in a distressed and unprofitable market. The corporation, said Dr. Davis, would address itself "to the task of conserving and maintaining the best that now exists in the way of sound education and modest scattered research in the rank and file of American colleges until this depression has passed and they are again able to take care of themselves." Were this very practical suggestion put into effect, college presidents and their faculties could attend to their more important educational tasks with greater efficiency and assurance of success. While a return to prosperity of our industrial and financial institutions will restore normalcy in educational financing, it will indeed be unfortunate if means cannot be found to keep colleges performing their important functions in a time when they are sorely needed.

Adversity Breeds Quality

NOT evil alone springs from the plights of economic depression, even for colleges. Aside from providing educational facilities to a maximum number of worthy and capable students, colleges have the quality of their educational processes and product to consider. A certain stringency in funds available for their work should serve to emphasize the desirability of eliminating whatever projects, functions, and individuals do not contribute most effectively to the objects in view. Economic pressure has a sobering influence on the young persons being educated, and education that is bought with sacrifice may be the more highly prized and more

thoroughly instilled because of the conditions under which it is acquired.

In the light of widespread unemployment among able engineers, the engineering colleges should give careful consideration to the character of the training they have to offer and to the quality and number of young men to whom it is offered. Present conditions and future prospects indicate more forcefully than it has ever been shown before that education should be not for specific jobs but for living in a world of rapidly changing social and economic environment and opportunity. An education that involves a breadth of knowledge, and that develops keen insight, wisdom, and easy adaptability to change, would seem to possess the most satisfactory elements of usefulness. Elsewhere in this issue Mr. Flanders pictures the engineer of the future as being a savior of the capitalistic system, persistently sought after by the financiers. Needless to say, the engineer that Mr. Flanders visualizes must possess superior knowledge and broad experience.

Aircraft in Warfare

REPORTS from Shanghai offer an instructive illustration of the military value of aircraft and what can be done by the side that has full control of the air. While it is known that the Chinese army possesses a considerable number of planes and fliers, only a few of them took part in the fighting around Shanghai, and those apparently made little impression on the Japanese.

The Japanese, on the other hand, possessed about 30 planes to each Chinese machine and the effect produced by them was entirely out of proportion to their actual number. They succeeded in causing very large fires, disorganized to a considerable extent the movement of Chinese forces, successfully bombed at least one troop train, and blew up roads. On some occasions pursuit planes attacked ground troops with machine guns.

Of course, Japanese planes would not have had such an easy time under normal war conditions. In this case, however, they had everything in their favor. The fighting took place within a very few miles of the Japanese air fields, which permitted operation with small supplies of fuel and an increased lifting capacity for carrying bombs. The Chinese aircraft defenses appear to have been inadequate, while the concentration of large forces within a comparatively small area permitted the Japanese to select their targets practically at will. The fact that the relatively few Japanese planes were apparently producing an effect superior to, or comparable with, their powerful navy and land forces, illustrates what a well-organized air force can do under favorable conditions.

One can only imagine what would have happened if the Chinese had had a good air force. It is only 490 miles from Shanghai to Sasebo, and the Japanese forces had to depend on supplies brought over that route.

Because of the harbor conditions in Shanghai and the shallow waters of the Yangtze river, the Japanese could use only small vessels, such as destroyers or the lighter cruisers. These had to come over a distance well within the range of modern bombers, and lay exposed in the river and harbor. It would not have taken more than a few small, well-placed demolition bombs to have disorganized the line of communications between Japan and China.

Economic Attitudes in Industry

THE Ohio State University has recently published a pamphlet entitled "Economic Attitudes in Industry," in which are analyzed the replies to a series of 15 questions addressed by certain members of the College of Engineering to a selected list of several hundred industrial leaders and economists. Our interest in the pamphlet lies as much in the attitude of mind that prompted the inquiry as in the results that it brought forth. It is stated that the inquiry arose out of a desire "to meet the ever more insistent demand that engineers be trained to understand and appreciate the social and economic implications of their work."

It is not practicable to reproduce here the questions that were answered by more than a hundred of the industrial leaders and thirty-three of the economists. As would be expected, sharp differences of opinion were often noted between economists and industrialists. For example, the industrial leaders questioned did not believe (75 to 4) in government ownership and operation of industries, while of the economists, 12 came out for it without reservations, 10 with reservations, 2 were opposed to it "at present," and only one was categorically against it.

Answering the question, "Do you believe that industries can be coordinated on a national scale entirely through efforts of individual enterprises?" 51 business leaders believed it could be done, 12 held certain reservations, 2 were doubtful, 2 predicated success on the leaders, and 13 were sure it was impossible. Among the economists, however, 16 believed it possible and only 3 opposed them, while 8 deemed it possible with some reservations.

In a summary of the report, kindly furnished to us by the Chairman of the Committee, Prof. C. A. Norman, it is pointed out that the replies showed a sympathy on the part of industrialists for certain social changes that radical elements and labor unions have been proposing, such as shorter working periods and old-age pensions. A majority appeared to believe that industry is tending to an 8-hour day and a 5-day week. Sixty-nine industrial leaders were for old-age pensions, 6 were for them with reservations, and 17 were opposed. From the replies it was indicated that the industries should provide these pensions without government compulsion. Of the economists, however, 14 favored industrial insurance under government compulsion, 8, pensions by taxation, 8, a combination of taxation and provision by industry, while only 5 thought that pensions should be provided exclusively by industry.

The complete report, which may be obtained free of charge by addressing the Ohio State University Experiment Station at Columbus, Ohio, contains the summarized answers to the entire list of 15 questions. Straws, perchance, of industrial and economic thought.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

STEAM RESEARCH IN EUROPE AND IN AMERICA—I

THIS is an abstract of four lectures delivered by Prof. Max Jakob before the University of London in the spring and summer of 1931. According to the opinion of Dr. Jakob, steam engineering until recently was far ahead of steam physics, advancing to ever higher pressures, exceeding even the critical pressure of 225 atm and progressing to temperatures of nearly 500 C. Physical science followed only slowly, partly because the investigation of highly compressed and at the same time superheated steam was only possible with the aid of apparatus, the construction and manipulation of which was not familiar to physicists. Dr. Jakob refers to work previously done, such as that of Professor Callendar, which he considers to be of the highest order, and of other investigations, including his own, under Professor Knoblauch, and that of Osborne in America. He also cites the more recent investigations carried out in Czechoslovakia, England, Germany, and the United States.

All these investigations were undertaken for the purpose of determining for water and steam, at all possible pressures and temperatures: (1) The specific volume, for calculation of the dimensions of steam engines; and (2) the total heat, for evaluating the heat balance of the same engines. This can be effected by direct measurements, or by indirect methods, namely, by using molecular or thermodynamic relations, leading from the volume to the total heat, and vice versa. Nearly all possible paths to this end have been traversed.

FUNDAMENTAL THERMODYNAMIC PROPERTIES OF WATER AND STEAM

MECHANICAL AND THERMOMETRIC MEASUREMENTS

In considering the fundamental thermodynamic properties of water and steam, Dr. Jakob begins with the direct measurement of the characteristic values p, v, and T, and gives a table summarizing the different measurements of these values with the names of investigators. The saturation line of steam was measured in Germany by Holborn and Henning, and at higher pressures up to the critical point by Holborn and Baumann. The latter found the critical values of 225 kg per sq cm and 374 C. The new American measurements of Keyes and Smith gave nearly the same values, namely, 225.8 atm and 374.1 C. Above 100 kg per sq cm, however, Keyes found higher saturation pressures than Holborn, the difference reaching nearly 0.5 kg per sq cm at 220 kg per sq cm. In England, Egerton and Callendar, Jr., quite recently checked these results against their own measurements and obtained close agreement with the German observations. According to the measurements and theoretical considerations of the late Professor Callendar, there should exist, above 225 kg per sq cm and 374 C, an unstable region, in which water and steam form mixtures, and only above 257 kg per sq cm and 380.5 C is a uniform state to be found.

The thermometers and gages used in these measurements are described in the original text, which also describes instruments used in other measurements. None of these descriptions can be reported here because of lack of space.

A particular lack of knowledge existed until recently regarding the specific volume of water, but this deficiency has been made good by recent experiments in America, England, and Germany. The values obtained by several experimenters are given in a table (III) in the original text. The values up to 300 C and 250 kg per sq cm agree with one another within 0 to 0.9 per cent; those up to 320 C and 300 kg per sq cm within 1.3 per cent; near saturation above 320 C the values of Trautz and Steyer are too high by a maximum of 3.7 per cent.

The specific volume of steam up to 10 atm was determined more than twenty-five years ago by Knoblauch, Linde, and Klebe, of Munich. Today the results of the measurements of Keyes and Smith are also available. These experiments cover specific volumes from 5 to 150 cu cm per gram, a pressure range from 1 to 183 (partially even to 246) kg per sq cm, and temperatures from 200 to 460 C. Professor Callendar, however, has proceeded the farthest, namely, even beyond the critical point.

More than thirty years ago Callendar established, by measurements in a steam engine and by other experiments, the following equations referring to the adiabatic change of state of superheated steam:

$$pv^{1.3} = \text{constant}$$

$$vT^{10/3} = \text{constant}$$

in which v is the specific volume, if the correction for covolume, as the specific volume of the molecules themselves has been named by van der Waals, is neglected.

Callendar carried out measurements of the specific volume near the critical point which led to such curious results that he did not try to publish them until about twenty years later. In these experiments Callendar found that at 374 C the densities of the liquid and the vapor were not equal as demanded by the theory of van der Waals and as observed by earlier investigators.

Contrary to this, as can be seen from Fig. 1, the density of water was found to be about 0.435, while that of steam was about 0.26 gram per cu cm. Only at 380.5 C (corresponding to 257 instead of 225 technical atmospheres) do the values coincide at the density of 0.375. The upper curve (for water) is observed, and the lower curve is interpolated. According to this, Professor Callendar supposed that, above 374 C, there exists an unstable region in which water and steam are mixed intimately. In this region, instead of a meniscus, there is to be seen a demarcation line, as is the case in layers of two liquids having nearly the same density. To maintain this appearance, absolutely pure steam is essential; Professor Callendar stated that the air contained in his steam was only one 10^9th part of the total weight. With the least impurity of the steam, mist is formed, and the line separating the two substances vanishes.

Since excellent new observations of the specific volume are now available in the region of liquid water, as well as in that of superheated steam, these observations being near the superheated line, it is possible to obtain this line itself by an extrapolation from both sides, which might almost be regarded as an interpolation.

Reference is made to the measurements of the Thomson-Joule effect in the United States, England, and Czechoslovakia, and the Havliček apparatus is shown and described.

CALORIMETRIC MEASUREMENTS

Calorimetric measurements form the main subject of the second lecture, and Dr. Jakob gives a table containing the names of investigators who have made such measurements of liquid heat, latent heat, specific heat of steam, and total heat. As to liquid heat i', he refers particularly to German measurements of Jaeger and von Steinwehr. The accuracy of the results of these measurements (4.1842 watt-sec per gram per deg C for the 15-deg calorie) is established by the investigators to be within a few ten-thousandths. Compared with the values of Barnes, those of Jaeger and von Steinwehr for 50 C are higher by about $1^1/_2$ thousandths.

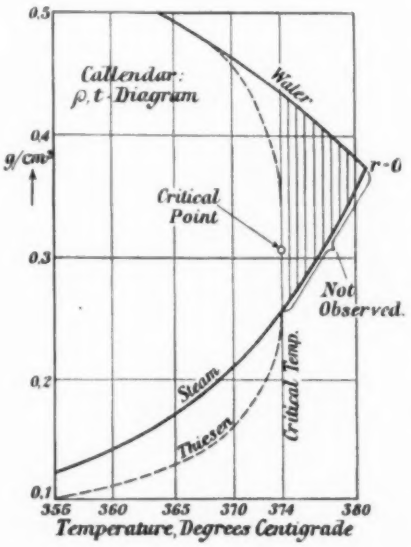

FIG. 1 TEMPERATURE-DENSITY CURVES FOR STEAM AND WATER

Dr. Jakob shows by a mathematical analysis that all that it is necessary to determine by experiment as functions of the temperature are α, the supply of heat energy without changing the content, β, the isothermal supply of heat energy and withdrawing of water, and γ, the isothermal supply of heat energy and withdrawing of steam, and if these values have been determined in a certain region it is possible to calculate from them all the thermodynamic properties relating to the saturation region of water and steam with the exception of v' and v'' (specific volume of 1 kg of water and specific volume of 1 kg of steam, respectively), for which we have to know the value of dp/dT along the saturation line.

The American authors have not given values for the specific heats c' and c'' and the specific volumes v' and v'', the latter being apparently omitted because the saturation line has not been determined in the Bureau of Standards.

Two further points are made regarding the heat content of water:

(1) At 15 C, *ceteris paribus*, the Bureau of Standards obtained a value of the total heat of water about 0.1 per cent lower than that of Jaeger and von Steinwehr, each of the two groups of investigators maintaining that their measurements were accurate to within a few ten-thousandths.

(2) The values found by Dieterici seem to be too high by 0.5 per cent, at most, below 200 C, and too low by 0.8 per cent in the region above 200 C. Fiock has corrected the values of Dieterici, and reduced them to the Bureau of Standards values. By this, above 200 C, the agreement is as near as 0.2 per cent. (Attention is called to the discrepancy in the values of the electrical equivalent of the heat unit, based on the measurements of the Bureau of Standards and of the Reichsanstalt, and the different definitions of these units.)

Direct measurements of the latent heat of steam at higher pressures have, up till the present, not been carried out anywhere in so wide a range as in the Reichsanstalt: first, up to 180 C (19 kg per sq cm) by Henning; then, twenty years later, by the same method but with entirely different apparatus, by Jakob up to 210 C (20 kg per sq cm), and, finally, in cooperation with his assistant W. Fritz, up to 310 C (101 kg per sq cm) These latter are now working in the region between 101 and 200 kg per sq cm. The principal reason why the latent heat is dealt with so thoroughly is that in the most technically important region this heat quantity signifies the greatest part of the total heat of steam. At 10 kg per sq cm and 450 C, for instance, the liquid heat is 180, and the energy of superheat 140 kilocalories per kg, whereas the latent heat is 180 kilocalories per kg, that is, 60 per cent of the total heat. Even at 100 kg per sq cm and 450 C the latent heat is still 41 per cent of the total heat, being nearly as much as the liquid heat.

The apparatus used by Jakob is said to differ considerably from the American apparatus. The most obvious difference between his calorimeter and that of Osborne is in the dimensions. Whereas the latter is designed for a water content of $^1/_2$ kg, Jakob's calorimeter has a capacity ten times as great. Notwithstanding its smaller form, the American apparatus was only suitable up to 50 atm, whereas with Jakob's the experiments could be carried out up to more than 100 atm without difficulty, and slight alterations mentioned in the original text will enable it to be employed up to 200 atm. The total height of Jakob's apparatus is about $1^1/_2$ m.

The fundamental equation of the method used by Jakob is given in the original text, and permits the calculation of the latent heat r in two ways. Both methods of calculation were used, but instead of starting from only two or three tests, each giving an equation referring to another mass m, Jakob and his associates always treated all experiments belonging to a certain temperature together, by the method of least squares. Certain further corrections are indicated. A graph in the original text ranging to 250 C and 40.5 kg per sq cm pressure is given to show how closely the different series of the German experiments connect with one another. Up to 56 kg per sq cm the difference between the Osborne and the Jakob values is always less than 0.2 per cent.

OPTICAL (SPECTROSCOPIC) MEASUREMENTS

Steam research can be approached through regions of physics which seem to lie off the main path, one such way being by the acoustic phenomenon of sound velocity. At this point, however, Dr. Jakob deals more in detail with modern optical methods based on the employment of theories concerning the behavior of the atoms in the molecule. In this kind of work the gram-molecule is used as a unit of weight and denoted as a mol. The methods of calculation of the energy of rotation of a diatomic and a triatomic molecule are presented, and the difficulties involved are briefly stated.

Spectroscopy is a method by which, from the place of the spectral lines in the spectrum, one can exactly determine the frequencies. This opens the possibility of determining by means of spectroscopic measurements that part of the specific heat which is not obtainable by the classical theory of mole-

cules. As in all problems of spectroscopy, the question consists (1) in obtaining clear and distinct lines, and (2) in interpreting them in a right manner. Neither condition is easy to fulfil.

The difficulties as regards the so-called "polar" or "heteropolar" molecules such as those of water consist in the fact that the spectra in question lie far in the ultra-red and cannot be fixed by ordinary photographic plates; further, they have a very great number of lines, and the fundamental vibration is difficult to determine; finally, there exist also optically inactive vibrations. Jakob tells how a way out of these difficulties has been opened up by the use of the so-called Raman effect.

In comparing the results of the spectroscopic and calorimetric methods, Jakob says, with reference to diatomic gases, that the spectroscopic method has already succeeded in determining the variation of the specific heat with the temperature probably more exactly than other methods, and that, regarding steam, we are quite near to this point. This, however, holds good only for atmospheric pressure. It seems to be of decisive importance to have a full knowledge of the polymerization, or, as Professor Callendar called it, coaggregation of the molecules.

The Callendar theory was published in 1900 and is restated by Jakob in his lecture. Callendar based his calculations on the value of $c_{p0} = \frac{13}{3} R$, where R is the special gas constant for steam. From measurements made in Munich it has been found that even at moderate temperatures c_{p0} is not constant but rises with the temperature. This Jakob considers as one of the weakest points in Callendar's system, though justified by expediency.

The author points out a minor defect of the Callendar system dealing with Callendar's expressions for v, and then proceeds to the consideration of Callendar's hypothesis that in each volume of water the same volume of steam is dissolved. From this hypothesis one obtains:

$$i' = c_i t + \frac{v'}{v'' - v'} r$$

Since this equation seems never to have been rigidly derived, Dr. Jakob proceeds to give a derivation. Imagine, he begins, an ideal liquid, differing from real water only by the singularity that no steam may be dissolved in it, and that its specific heat may be denoted by c_i, where c_i signifies the well-known minimum value of the specific heat of water. Now one can suggest that 1 kg of real water, the specific volume of which is v', originates in the following way: the volume v' may be firstly filled by ideal water, and then the same volume of steam, that is, v'/v'' kg of steam, dissolved in it. To produce this mass of steam one needs the heat quantity $(v'/v'')r_i$, where r_i signifies the latent heat of ideal water. Since, after this a part of the real water consists of dissolved steam, the evaporation of 1 kg of real water requires only the heat quantity:

$$r = r_i - \frac{v'}{v''} r_i = \frac{v'' - v'}{v''} r_i$$

from which it immediately follows that

$$r_i = \frac{v''}{v'' - v'} r$$

Now, according to Callendar's hypothesis, the heat content of real water is

$$i' = c_i t + \frac{v'}{v''} r_i$$

and substituting r_i from the preceding equation, one obtains Callendar's starting equation

$$i' = c_i t + \frac{v'}{v'' - v'} r$$

as required.

Substituting in this equation, according to the formula of Clapeyron-Clausius,

$$\frac{r}{v'' - v'} = \frac{1}{J} T \frac{dp}{dT}$$

one obtains

$$i' = c_i t + \frac{1}{J} v' T \frac{dp}{dT}$$

It is remarkable, but has apparently been forgotten that Callendar started originally from this equation, established as early as 1889 by J. M. Gray, and adopted in the year 1902 by Callendar, and that the suggestion of the "ideal water," on which Gray based his equation, was originated even by Rankine.

In developing the above equations Callendar finally obtained an equation for the saturation pressure, and Jakob says that the saturation pressures calculated according to this formula deviate from the best-known experimental values by less than ±1 per cent in the region from 200 to 374 C. This is an astonishingly good result if one considers the way in which it was obtained. However, Callendar's theory does not correspond entirely to reality, since as shown in Table VII of the original text, the best experimental values agree at least by 0.1 to 0.2 per cent.

Jakob mentions that the equation of the saturation pressure (44 in the original) is said to hold good even beyond 374 C, up to the extraordinary temperature of 380.5 C. On the contrary, the equations of the total heat and of the specific volume (28 and 29) are said to fail at the saturation limit from 374 deg to 380.5 deg. If Jakob understands Callendar in this respect, these equations give only the specific volume of steam when separated from the water by a meniscus. But beyond 374 C, instead of the meniscus a horizontal separation line exists, which Callendar calls a "demarcation line," and we have now to do not with water and steam, but with two water-steam mixtures. Below 374 C (225 kg per sq cm) water and steam are mixtures of molecules of different complexity. The water molecules decrease in complexity with increasing temperature, whereas the number of complex molecules in the vapor increases with rising pressure. Raising the pressure beyond 225 kg per sq cm, the molecules in the part occupied by steam become still more coaggregated and at the same time less in number, and since, according to Callendar's hypothesis, as many steam molecules are always dissolved in the water as exist in the same volume of steam in equilibrium with the water, the numbers of steam molecules also, still present in the water, must continually decrease until, ultimately at 380.5 C, all steam molecules are condensed and the mixture has taken on the properties of water. It is just this hypothesis of the equality of the dissolved steam volume with the water volume, which leads most naturally to the relations

$$v'' = v', \quad i'' = i', \quad \text{and} \quad r = 0$$

which signify that now there exists no longer any difference between the steam of highest complexity and the water. At the same time this is a theoretical corroboration of the sug-

gestion, appearing rather arbitrary on first sight, that exactly as many molecules of steam should be dissolved as exist in the same steam volume. Another explanation of this suggestion was formerly given by interpreting the water surface as a film semi-permeable to steam molecules. (*Engineering*, vol. 132, nos. 3420, 3432, 3433, 3436, 3437, 3438, 3439, and 3441, July 31, Oct. 23 and 30, Nov. 20 and 27, Dec. 4, 11, and 25, 1931, pp. 143–144, 518–521, 550–551, 651–653, 684–686, 707–709, 744–746, 800–804, illus., *et A.* Part II will appear in the May Issue.)

Short Abstracts of the Month

AERONAUTICS

Measurement of the Drag of Small Streamlined Bodies

RECENT research has shown that the large variations in the drag of a streamlined body frequently obtained in different wind tunnels, or even in the same tunnel at different times, are due to variations in the state of the boundary layer of the body. Within the normal wind-tunnel range of Reynolds number, it is found that the boundary layer is partly laminar and partly turbulent, and the ratio of the lengths of the surface over which these two states exist, and upon which the drag partly depends, is materially affected by the degree of turbulence present in the airstream. Complete wind-tunnel data for a streamlined body should therefore include a specification of the ratio of laminar to turbulent layer.

As a means of promoting turbulence in the boundary layer, the fixing of a number of rings of fine thread to the surface of the body in transverse planes near the nose was suggested in R. and M. 1271 as being the most convenient from a practical point of view, and this means was employed in the present experiments.

To provide comparative data, as in the interference work now proceeding, and where full-scale performance does not have to be predicted, the most important point is that the body drag as measured in the tunnel shall not be subject to variation from day to day or in different tunnels. It would seem to be sufficient to use enough threads to give a curve of drag coefficient against Reynolds number of what may be termed the turbulent type. (E. Owen and C. T. Hutton in *Reports and Memoranda, Air Ministry, no. 1409 (Ae 530)*, June, 1931, *e*)

ENGINEERING MATERIALS

Machinability of Free-Cutting Brass Rod

BRASS rod for use in automatic screw machines is one of the major products of the brass mills. Higher speeds of cutting are desired, and this paper is a report of the results of tests undertaken in an effort to obtain the measure of the effects of such variables as lead content, microstructure, and cold work on the machinability of brass rods. The author includes within the province of the term "machinability" such things as power, finishes, and tool life. In practice it is sometimes found necessary to sacrifice some of these in order to obtain a rod that will not tend to throw up a burr, or will give a burr which is easily tumbled off. Again, a specially stiff rod may be necessary because of long overhang from the chuck, or a rod of special characteristics is needed to take a given broaching operation without chattering. It is only through an understanding of the effect of basic mill operations on the machinability of the rod that such problems as these may be solved most economically.

The testing apparatus used was of the single-tooth milling-cutter type, in all respects similar to that first used and described by J. Airey and C. J. Oxford in Trans. A.S.M.E., Vol. 43, p. 54, and by O. W. Boston in Trans. A.S.S.T., Vol. 16, No. 659.

The tests have shown that within the range of copper contents met with in practice, the unit cutting energy seems to depend largely on the percentage of lead present. A small amount of lead added to a Muntz metal produces a decided improvement in its machinability, but comparatively little is to be gained by increasing the lead content above 3 per cent. No tests have been made to determine the effect of such impurities as tin and iron.

As regards microstructure in the lower range, the unit-cutting-energy curve follows the beta curve and does not reflect the higher hardness value due to the fine grain size. The point of maximum machinability (lowest energy consumption) corresponds with the point of minimum beta content. Cold drawing has been accompanied by a considerable improvement in machinability. In two instances noted, however, the first light draw produced a small increase in energy consumption, which was followed by a consistent decrease with further cold work.

The tensile strength of a Muntz metal increases and its ductility decreases with a rise in the beta content and with cold drawing. It has been shown that machinability decreases with rising beta content and improves with cold working. It is evident, therefore, that the machinability of a given piece of brass rod cannot be predicted through consideration of its tensile properties. In his discussion of the paper by Boston, mentioned earlier, H. L. Daasch suggested that shearing strength, or a function of elongation and shearing strength, might be used to indicate relative machinability. No work of this nature has as yet been undertaken. (Allen Morris, Research Engineer, Bridgeport Brass Company, in *The American Institute of Mining and Metallurgical Engineers Technical Publication no. 454*, pp. 3–10, 11 figs., *e*)

FORGING

Die Forging

THE present article describes various machines used in die and drop forging, including the Bêché twin-cylinder pneumatic hammer with four guide rods. The cylinders are disposed one on either side of the anvil block and below the floor level. The piston rods, which have a yielding connection with the hammer, are subject to tension stresses when the blow is struck, and it is claimed that it is due to this fact, as well as to the reduction in inertia due to the lighter rods, that the maintenance of that part of the mechanism of the hammer is considerably reduced.

The choice of a hammer depends, among other things, on the industry in which the drop forgings are to be used, the quantities required, the size and weight, and the motive power and type of labor available.

One of the most interesting parts of the article deals with electric forging machines in which the bar is heated electrically and at the same time progressively upset as it becomes hot enough to forge. The article illustrates three such ma-

chines, the Omes, the Languepin, and a 50-kw Wenninger. In the latter it is possible to upset 15 diameters or more without danger of folding or getting a cold shut in the metal. A brief reference is made to the Giacchino electric upsetter, in which, among other features, the anvil is capable of being advanced or withdrawn during the upsetting operation, by which means perfect upsets may be obtained containing 20 to 30 diameters of bar. The earlier types of these machines were developed primarily for the manufacture of poppet valves for internal-combustion engines. A section of an electrically upset valve head is shown in the original article, and the types of presses used with electric upsetting machines are illustrated. (F. W. Spencer in *Machinery* (London), vol. 39, no. 1001, Dec. 17, 1931, pp. 360–363, 14 figs., *d*)

FUELS AND FIRING

Tests on the Continuous Carbonization of Finely Crushed Coal by Radiant Heat

THIS study was undertaken for the purpose of determining the economic possibilities of the White process of low-temperature carbonization, but in addition the effects of varying retort temperatures and coal sizes were studied.

In the White process the coal is crushed to a moderately fine condition and allowed to fall through a heated vertical retort. The gas, tar, and other by-products are removed according to the usual carbonization practice, and the solid granular residue which collects at the bottom of the retort is withdrawn as required to give a continuous process.

It has been found that the limiting factor determining the rate at which coal can be carbonized in a retort is the rate at which heat can be forced through the retort wall.

The paper contains an interesting discussion of the commercial features of low-temperature carbonization. The first impetus to the development of low-temperature carbonization was given during and for several years following the World War. The petroleum and natural-gas reserves were thought to be rapidly diminishing, and low-temperature coal tar and gas were the immediate substitutes in view. Smokeless domestic fuels could command some premium over raw coal by virtue of their superiority in combustion. Bituminous coal suitable for low-temperature coking was and is abundant. The prospect for many processes to become firmly established was good. Consequently the spirit of low-temperature-carbonization research caught hold and considerable work was done. Many processes were evolved, some receiving very little consideration, while others were promoted in a large way and commercial installations made. To the authors' knowledge none of them have been economically successful, and thus none have survived. Today the situation is different. We now apparently have unlimited resources of both oil and gas. The tars from by-product coking are diminishing in value, and those from low-temperature coking are of very uncertain value. The gas yield cannot hope to add much to the revenue from the process. Other by-products with our present knowledge are of little value. Thus, the enhanced value of the solid residue over that of raw coal is the only hope of appreciable gain. It appears, therefore, that any process to be worthy of consideration on an economic basis must utilize a very cheap coal, and must be simple and inexpensive to operate.

Any process worth considering for low-temperature carbonization must be quite simple and require a minimum of mechanical effort, continuous processes being essentially preferable to those of intermittent nature.

The paper discusses next a method of continuous carbonization with gravity flow, and particularly the method of carbonization in which crushed coal is allowed to fall through a hot vertical retort, mentioning among others the McEwen process in England where powdered coal is dropped through a vertical retort through which hot products of combustion are ascending, and the White process, in which carbonization is effected on crushed coal when dispersed into the top of a heated vertical tube.

In the discussion of the experimental set-up, considerable attention is devoted to the construction and operation of the electrical precipitator. The products obtained in these experiments were

1 A granular residue comparable in size to the coal fed and of lower volatile content
2 A small quantity of dust which should be included in the fines of the residue, but is carried from the retort in the gas stream on account of its fineness
3 A fixed combustible gas
4 Tar of a mid-temperature type
5 Light oil scrubbed from the gas
6 Ammonia scrubbed from the gas.

As to utilization of products, it is stated that the residue produced by this process has been considered as suitable for burning only in powdered or briquet form, but not as produced. Tests made of the latter form were unsuccessful, and as a pulverized fuel it did not give as favorable results as had been hoped. It is not believed that acceptable briquets can be made of the residue without first grinding it. The gas, tar, and ammonia do not call for any special comment.

The light oil scrubbed from the gas is a mixture essentially of benzene, toluene, and xylene. It may be refined to yield these specific chemicals, which are used as solvents and as raw materials in the chemical industries. The light oil also has value as a motor fuel, being used usually as a blending material to improve the knock rating of gasoline. (Floyd B. Hobart and F. J. Demorest in an investigation in cooperation with the Battelle Memorial Institute, *Ohio State University Studies, Engineering Series*, vol. 1, no. 1, Jan., 1932, 39 pp., 16 figs., *e*)

HYDRAULICS

The Grid-Constricted Orifice

THE grid-constricted orifice is a new apparatus for measuring the flow of water. It is claimed that the loss of pressure in this apparatus is less than in the case of the venturi tube, although the length of the apparatus is barely greater than that of a measuring nozzle. The basic principle of this device, shown in Fig. 2, consists in the subdivision of the area of the orifice into a number of smaller ones, each of which is a section varying like a venturi tube. The passages therefore decrease in cross-section in the direction of flow until they reach a certain minimum area, and then expand gradually. The simplest way of obtaining such orifices is to place a number of streamline-profiled bars side by side and normal to the direction of flow, that is, bars with a thick forward edge and a sharply contracting rear edge. These bars will then lie somewhat like those of a grating, whence the name given to the apparatus.

Fig. 2 shows the parallel streamlined bars in longitudinal cross-section. The reading of pressure P_1 takes place at the thick front edge of the bar, while the pressure P_2 is taken at

the narrowest place in the passage. Here the weir pressure of the flowing liquid is fully utilized for purposes of measurement. The necessity for taking into consideration the velocity of inflow of the liquid present in other weir-type devices is absent here, and the coefficient of flow for all conditions of contraction thereof is very nearly the same and differs but little from unity. The pressures are conveyed to the indicating devices by longitudinal passages bored in the profiled bars. Fig. 2 shows the constructional details of the bars of the grid. *d* is the case equipped with two flanges and containing the orifice proper. This case is provided with the ring-shaped passage *e*, divided in two by bosses. Circular wedges in the bosses keep the orifice from turning in its case. One half of the profile bars have passages bored in them on the front side, and the other half have similar passages located at the narrowest part of the cross-section of flow and distributed over the entire length of the bars. These passages open into longitudinal passages in the bars themselves, and are shut off on one side in such a manner that the bars used for indicating pressure P_1 connect with one side of the circular

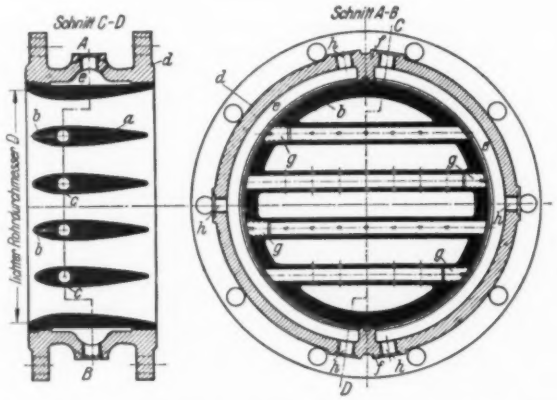

FIG. 2 GRID-CONSTRICTED ORIFICE FOR MEASURING THE FLOW OF WATER [350 MM. (13.8 IN.) I.D.]

(*a* = streamlined bars; *b*, place for reading off pressure P_1; *c*, place for reading off pressure P_2; *d*, casing; *e*, circular passage; *f*, plug; *g*, closed end; *h*, jig for attaching differential-pressure-measuring device; *D*, inside pipe diameter; *Schnitt*, section along.)

passage *e* of the case, while those used for indicating P_2 connect with the other side. The differential-pressure-measurement devices are attached at holes *h*. These holes are located on top, below, and at the side of the bars in order to make the installation easy under various conditions. The holes that are not used are closed by plugs. The grid-constricted orifice is suitable for measurements of flow through rectangular cross-sections, and except the overflow weir for open channels, there is today no throttle-type device available for measuring such flow. The same profile bars can be used for different cross-sections and velocities of flow of water, provided the number of the bars and their distance from each other are properly selected. Wherever large cross-sections are employed, it is recommended that the bars be reinforced by means of cross-pieces, which latter should be preferably stream-lined as well. The bars together with their reinforcements then constitute a screen with individual orifices, which latter may also be produced by boring them to the proper section.

The article gives extensive data as to tests carried out by means of this device and its underlying theory. (Prof. Ernst Schmidt in *Zeitschrift des Vereines deutscher Ingenieure*, vol. 75, no. 51, Dec. 19, 1931, pp. 1535–1538, 9 figs., *d*)

INTERNAL-COMBUSTION ENGINEERING (See also Motor-Car Engineering: Carburetion of the Packard Twin-Six Car)

Diesel-Engine Exhaust-Gas Temperatures

TABULATED readings are given for an eight-cylinder four-stroke-cycle single-acting engine of about 3000 hp. These data show that when an engine is adjusted in accordance with exhaust temperatures, the difference in the cylinder powers is better equalized, and hence a smoother running and more reliable performance obtained. A low exhaust temperature, consistent with the type and design of the engine, means a high CO_2 content and economical combustion. With accurate exhaust pyrometers and careful watching of them, damage to exhaust valves, valve seats, and piston rings can largely be avoided, while failure of the jacket and piston cooling-water pumps is indicated by the pyrometers before serious damage is done. It is very important to have the pyrometer readings accurate and reliable. A table in the original article shows that a variation of 30 C (54 F) in the maximum difference between the exhaust pyrometer readings represents a difference of 25 ihp. Hence the maximum instrumental error allowed in exhaust pyrometers should not exceed 5 C, which would represent a maximum difference of 10 C between any two pyrometers. (*Gas and Oil Power*, vol. 26, no. 315, December 3, 1931, p. 359, *dpa*)

The Lanova Diesel Engine

THIS engine was designed by Franz Lang, of Munich, originator of the Acro engine, and involves the feature of ordered air flow or turbulence. It is claimed to operate at an unusually high mean effective pressure and with a very low proportion of excess air. A diagram of the combustion chamber, which is located in the cylinder head, is shown in Fig. 3.

In plan view the combustion chamber is approximately heart-shaped. At one side of the combustion chamber proper there is an air-storage chamber communicating with the former, and directly opposite the air-storage chamber is located the spray nozzle. The operation of the engine is as follows:

At the end of the compression stroke there is a certain amount of air under pressure in the air-storage chamber, and fuel is sprayed into the entrance to this chamber across a part of the combustion space. It is supposed that when the tip of the spray jet reaches the entrance to the air chamber it has been heated to such a degree that ignition takes place before the fuel enters the chamber itself. Since injection begins some time before dead center, the fuel will be already ignited when the piston starts on the expansion stroke. The air in the storage chamber now rushes out of that chamber in a direction directly opposite to the spray, thus helping to further atomize the fuel. Owing to the shape of the combustion chamber, the air will be caused to swirl therein in

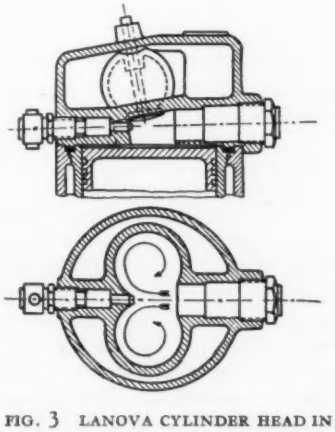

FIG. 3 LANOVA CYLINDER HEAD IN VERTICAL AND HORIZONTAL SECTION

the discharge of the storage chamber. Two swirls are produced, which are tangent to each other at the axis of the fuel jet. Since the direction of these swirls is contrary to that of the jet, it is claimed that this brings practically all of the fuel particles in intimate contact with air, thus permitting the combustion of a very high proportion of fuel to the air content of the combustion chamber. It is stated that in this way the air-excess coefficient has been reduced to the very low figure of 1.10 under favorable circumstances.

The engine uses a compression ratio of between 12 and 13 to 1, resulting in a compression pressure of from 380 to 440 lb per sq in., and the cycle employed is closer to the constant-pressure than to the constant-volume cycle. The pressure increase on ignition is said to be in the ratio of about 1 to 1.5, hence the maximum combustion pressure ranges between 540 and 630 lb per sq in.

A single-cylinder experimental engine with a bore of 2.95 in. and a stroke of 6.30 in. was operated at 1400 rpm, and it is believed that higher speeds can be obtained with multi-cylinder engines of the Lanova type. Special arrangements for starting are provided.

A report of tests of the Lanova engine was published by Dr. Loschge in the special Diesel number of *Zeitschrift des Vereines deutscher Ingenieure*, dated June 28, 1931. (*Automotive Industries*, vol. 66, no. 4, Jan. 23, 1932, pp. 126–127, 2 figs., *d*)

Injection, Ignition, and Combustion in High-Speed Heavy-Oil Engines

THIS is a more or less general paper, and only certain parts of it can be abstracted.

The question of the pressure waves set up in the fuel pipes is today much under discussion. As it determines the velocity of propagation of the wave it is necessary to consider the relative influence of the compressibility of the fuel and the increase of volume, i.e., the elasticity of the pipe under pressure.

For instance, taking figures typical of present practice, assume a fluid pressure in the pipe of 2000 lb per sq in. and a ratio of external diameter to bore of the pipe of 2, so that it must be treated as a thick cylinder: with a steel pipe, the increase of volume of the pipe under these conditions is 0.025 per cent, and the decrease of volume of the oil is 0.75 per cent. So that the increase of volume of the pipe is about one-thirtieth of the decrease of volume of the oil, and therefore the bulk modulus of elasticity of the oil "in the pipe" is 96 per cent of its "real" value. With a brass pipe under the same conditions this becomes 93 per cent.

Now a disturbance in the fluid in the pipe, such as a pressure wave caused by the compression stroke of the pump, is propagated through the pipe with the speed of sound, $v_s = \sqrt{(K/\rho)}$, where K is the bulk modulus of elasticity, and ρ is the density of the fluid. K is thus the bulk modulus of the fluid "in the pipe." Thus, for a fuel oil of specific gravity 0.86 and K equal to 266,500 lb per sq in., the speed of sound is 4800 ft per sec, some hundreds of times that of the actual flow. Such waves may be wholly or partially reflected back at the nozzle, and may again be reflected at the pump end to move again toward the nozzle. During the normal period of injection in a high-speed engine, and with an average length of pipe, such waves may travel several times to and fro through the fluid in the pipe. These pressure waves may appreciably affect the pressure at the nozzle, which, of course, determines the flow from the nozzle, and in an analysis of the injection process they must be taken into account.

To simplify such an analysis, it will be assumed: (*a*) that the pump plunger is of same diameter as the pipe, (*b*) that the pump plunger moves with constant velocity, admission and cut-off being port-controlled, with instantaneous beginning and end of delivery, and (*c*) that, by virtue of the compressibility of the oil, the fuel next to the plunger is, during the early part of the delivery period, subjected to a high constant acceleration, so that after a small fraction of the delivery stroke this oil is moving with plunger velocity. With these assumptions, a typical case has been worked out using the following data: bore of pipe, 0.044 in.; length of pipe, 23 in.; velocity of plunger, 25 ft per sec; time of delivery period from the pump, 0.004 sec; the bulk modulus of oil "in the pipe," 266,500 lb per sq in.; specific gravity of fuel, 0.86; corresponding speed of sound "in the pipe," 4800 ft per sec; pressure in engine cylinder during injection rises from 300 to 800 lb per sq in.; nozzle of "open" type with an effective area of one-fortieth that of the pipe.

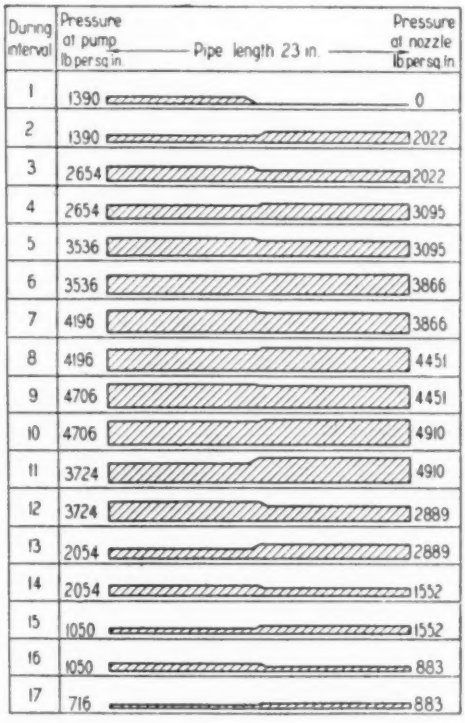

FIG. 4 PRESSURES IN FUEL PIPE OF HIGH-SPEED DIESEL ENGINE DURING INJECTION

The author shows that when the fluid at the pump plunger is set in motion the increase in pressure is directly proportional to the increase in velocity of the fluid. Hence, the front of the pressure wave thus set up is a straight line showing uniformly increasing pressures up to a maximum of

$$P = \frac{\text{Bulk modulus}}{\text{Speed of sound}} \times \text{Velocity of plunger}$$

$$= \frac{266{,}500}{4800} \times 25 = 1390 \text{ lb per sq in.} \quad [1]$$

The time for this pressure wave to travel the length of the pipe (23 in.) is $23/(12 \times 4800) = 0.0004$ sec, or one-tenth of the delivery period. Fig. 4 shows, during the complete period of injection, variations of pressure in the pipe for successive intervals of 0.0004 sec. The preliminary period during which the fuel at the plunger acquires the velocity of the plunger is assumed to be short, and this is indicated, in each case, by

the short sloping front of the pressure wave. At any instant during interval 1 the pressure at the plunger is 1390 lb per sq in. and at the nozzle is zero, the distance the wave front has traveled being proportional to the fraction of the interval that has elapsed.

At the end of interval 1 the wave reaches the nozzle and injection begins. If the pipe end were closed the pressure wave would be completely reflected; if the nozzle area were equal to the pipe cross-sectional area, there would be no reflection. The actual case is one of partial reflection, the height of the reflected pressure wave depending on the resistance offered to flow through the nozzle. In the case considered, the initial pressure wave is one of 1390 lb per sq in., while the pressure of the reflected wave is 632 lb per sq in., giving a total pressure of 2022 lb per sq in. With complete reflection this pressure would have been 2 × 1390 or 2780 lb per sq in., and the difference is accounted for by the velocity of the oil through the nozzle.

The author shows how to find the magnitude P_1 of the reflected wave. The conditions at the nozzle remain constant until the wave, which is completely reflected at the pump plunger at the end of interval 2, again reaches the nozzle at the end of interval 3, when a similar calculation is carried out for the next reflected wave. This process is continued throughout the delivery period of the pump, that is, up to the end of interval 10, during which the pressures at the nozzle and the corresponding velocities are increasing. The pressure in the pipe at the end of any interval may be checked by considering the displacement of the plunger and the outflow through the nozzle up to the instant considered.

At the end of interval 10 the pump plunger stops, in effect, and the wave reaching the plunger at this instant is not reflected. Instead, the oil next to the plunger is brought to rest and a negative wave of 1186 lb per sq in. due to the resulting drop in velocity of the oil, travels toward the nozzle. When this reaches the nozzle it is partly reflected, the flow from the nozzle continuing, and the magnitude of the negative pressure wave is calculated in a similar manner to the above. This process continues until the pressure at the nozzle is equal to that in the cylinder. From this point, with the "open" nozzle considered, the oil still under pressure in the pipe expands into the cylinder only as the cylinder pressure falls.

Another illustration shows the variations in V_n or the velocity through the nozzle, illustrating the effect of length of pipe. Diagrams showing the rapid damping of pressure waves in pipe lines are given in the original article.

By far the majority of fuel nozzles on high-speed engines are either of the open type or of the spring-loaded automatic-valve type. In the case of open nozzles the ratio of the effective area through the nozzle to the cross-section of the pipe is a factor, and the smaller the nozzle the higher is the pressure in the piping and the longer is the period of fuel injection. The advantage of the open type of nozzle is its simplicity; its drawback is the relative lack of control over the injection after the pump has ceased delivery, with the possibility of dribbling as the velocities through the nozzle fall off. The spring-loaded valve offers better possibilities due to the introduction of two further means of controlling the injection: the strength of spring acting on the valves at the nozzle may be set to open at any desired pressure; and the effective area of cross-section through the valve at various lifts can be given any desired value by employing a valve of suitable shape.

In dealing with the processes within the cylinder the author offers an explanation of ignition lag. According to this explanation the chief factor is the rate of heat transfer from the air to the droplets of oil, while evaporation plays at least a minor part in the process. This is illustrated by diagrams showing cylinder conditions during the compression stroke in three German engines of quite different design as obtained by Neumann.

These diagrams throw a light upon other questions such as effect of relative motion between fuel and air, and effect of penetration of fuel into the air, with resulting differences in atomization. The conclusions to which the author comes are that a short ignition lag may be associated in engines of different design either with a high or with a low rate of pressure rise, and that it would be dangerous to apply conclusions concerning ignition lag and rate of pressure rise drawn from any one engine to another engine in which the processes of injection and distribution of the fuel are not exactly similar.

The author makes certain inferences concerning the desirable form of indicator diagram. Referring to Fig. 5, it may be

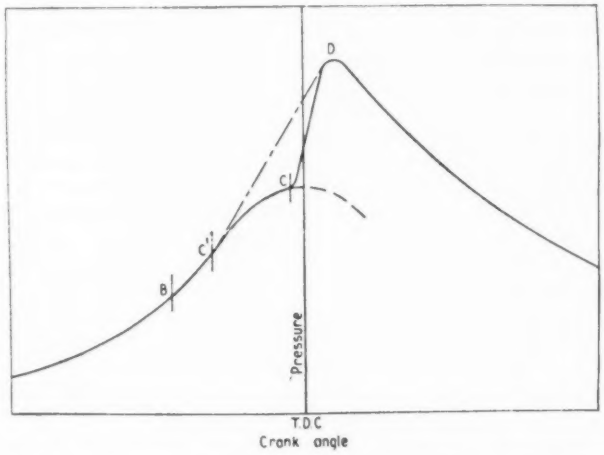

FIG. 5 INDICATOR DIAGRAM OF HIGH-SPEED DIESEL ENGINE SHOWING EFFECT OF REDUCING IGNITION LAG

said that the position of points *D* and *B* are relatively fixed; the maximum pressure at *D* is limited, in a particular design, by questions of strength, and its position with respect to inner dead center by the question of thermal efficiency; the "earliness" of *B* is limited by the rate of heat transfer from air to fuel possible with a particular design. So that, the maximum interval from *B* to *D* being limited, the problem is to make the best possible use of this interval.

This interval is made up of *BC*, the ignition lag, and *CD*. Thus, by reducing the ignition lag, as from *BC* to *BC'*, the interval available for the rise of pressure to *D* is increased, and the mean slope, showing the mean rate of pressure rise, decreased from the solid line *CD* to the broken line *C'D*. This change will, at the expense of a slight increase of negative work during the compression stroke, lead to greatly improved smoothness of running and general reliability. To this end, therefore, a reduction of ignition lag, and a suitable control over combustion conditions, to give the curve *BC'D*, should be the objectives of further development work.

Fuels from different sources behave differently in any particular engine both as regards ignition lag and smoothness of running, but little is known of the circumstances determining this behavior. Predetonating dopes or ignition accelerators have been proposed for the reduction of ignition lag. Small quantities of amyl nitrate and ethyl nitrate are said to have been beneficial.

In general, it would appear that a short ignition lag and a satisfactory rate of pressure rise may be attained by speeding up the chemical reactions prior to ignition. Engine design may have this desired effect by facilitating the transfer of heat from air to fuel, and the composition of the fuel itself has an important bearing on its behavior in an engine. Fuels at present unsatisfactory might with the addition of other substances be rendered suitable for use in high-speed engines.

The discussion cannot be abstracted because of lack of space. (S. J. Davies, Ph.D., and E. Giffen, in a paper read at a meeting of the *Diesel Engine Users' Association*, March 31, 1931; published by the Association, original paper, pp. 1–19, 15 figs., appendices pp. 20–21, 1 fig., and discussion pp. 22–39, figs. 17–25, *t*)

MACHINE PARTS

Test of Walker-Holroyd Worm Gear

THIS test was carried out at the National Physical Laboratory, England, on a 6-in. gear with a ratio of 7 to 27, the Daimler-Lanchester worm-gear testing machine used being described in some detail in the original article.

In the manufacture of the gear a hob is used for cutting the teeth. The hob profiles must be relief-ground in order to eliminate hardening distortion and to give a keen and uniform cutting edge. A relieving lathe with grinding attachment is necessary for this purpose, and the finished hob depends for its accuracy on the accuracy of the lead-screw cams and gears used on the lathe. A disk grinding wheel cannot be used for worms of high lead angle and consequently a pencil wheel must be used, and owing to the small diameter of the wheel at the bottom end, it must revolve at a very high speed. The necessary shape of hob profile may be obtained on the grinding wheel by means of an accurate pantograph, and exact spacing of the gashes is important if errors are to be avoided. The hob may be made in two sections, the first section being tapered and used for roughing out the toothed spaces and taking the metal out of the bottom of the spaces. The second section of the hob is then used only for finishing the sides of the teeth. The accuracy of the tooth-to-tooth spacing depends on the mounting of the table on which the worm wheel is mounted during cutting.

In the Holroyd worm-gear generator the drives are as far as possible carried out by means of hardened and ground spur gears. The accuracy in the worm is of greater importance than accuracy of the wheel, but is much more difficult of attainment owing to the fact that a worm has both an axial and circumferential pitch, and a worm-thread grinder is not by any means a simple piece of mechanism. In the Holroyd worm-thread grinder the main drives are carried out where possible by hardened and ground spur gears, and the drives to the lead screw and dividing mechanism are made separate so that each can be tested independently for errors and adjustment made if necessary. The machine has a hydraulic speed control for the forward and return motions.

In the tests the maximum efficiency obtained was 97.6 per cent. This figure was obtained under various conditions of speed and power, including the maximum speed and load of 86 hp at 2000 rpm. The highest efficiencies were obtained under the maximum load, which is said to be contrary to the results made in previous tests of gears. Measurement of temperature rise of the oil in the gear box is supposed to indicate the power loss, as the rate at which heat is generated in the gear teeth is directly proportional to the latter. It is claimed that the temperature rise in the test of the new gear is only slightly more than half of the temperature rise of other gears when transmitting the same load. This is important, as a worm gear can easily be ruined by overheating of the oil. (H. Walker, Technical Engineer, John Holroyd Co., in *The Automobile Engineer*, vol. 22, no. 289, Jan., 1932, pp. 28–30, 5 figs., 1 table, *d*)

MACHINE-SHOP PRACTICE (See Engineering Materials: Machinability of Free-Cutting Brass Rod)

MACHINE TOOLS

British Machine Tools

THE main features of recent innovations comprise heavier construction, greater driving power at higher speeds, more extensive range of feeds, short driving shafts to reduce torsional stress and bending between bearings, employment of alloy gears and shafts, and anti-friction bearings, including those of lathe centers.

The use of unit construction continues to expand in England, and the same can be said for the application of hydraulic power.

As regards lathes, it is found that in one type there is a preloaded spindle-bearing arrangement for the front of the headstock, consisting of a double-row spherical roller mounting, with the outer ring made in two portions. A ground shim determines the degree of loading, so that excess of pressure cannot crush the rollers. As wear occurs, the shim may be reduced to suit.

Four sizes of lathes have been developed by one firm for use with tungsten carbide tools. Parallel gun-metal bearings with ball thrust washers carry the spindle in each case. The $12\frac{1}{2}$-in.-center-size lathe has 18 speeds up to 300 rpm, and there are 20 feed changes besides 40 screw-cutting changes. Cuts on cast iron have been taken at 460 ft per min with a Widia tool. A 24-in.-center lathe has been built to operate up to 40 ft in length. Sixty-ton steel has been turned at a rate of 200 ft per min with Widia. A double-ended lathe has been constructed to receive 85 ft between centers, or 73 ft with both heads in use. No fewer than 90 speeds are obtainable on each head with a variable-speed motor and change gearing. Instead of mounting separate motors for rapid traverse of the three saddles, they all obtain power from one motor, using clutches for connection. The two loose heads can be moved by coupling them to the saddles as required.

Several improvements have been made in hydraulic multi-cut lathes. These new features include a peculiar device to catch hold of ribbons of metal as they come from the tools, pull them away and pass them to the suds tray, where a continuous conveyor makes certain of their complete removal from the lathe. Without this provision the machine might completely choke up on certain kinds of work. The check valve has been redesigned to give better control over feed rates, especially very slow ones, which sometimes present a difficulty. A demonstration has been made at a rate as absurdly slow as one inch in half an hour.

An unusual feed principle has been introduced in a stub lathe of the multi-tool type. The front slide is vertical, the back one sloped. Diagonal racks and linkwork give cross-feed to the rear slides, and by substituting other racks with teeth at a different angle, the feed may be changed.

In an automatic chucking machine, the headstock is adjustable longitudinally by means of a graduated screw. This provision enables compensation to be made for variations in dimensions of rough pieces, this endwise setting avoiding any

need for disturbing the tools or their supports. The usual overarm to the capstan is objectionable because it restricts the dimensions and swing of tools. It has now been omitted and the mounting improved to compensate accordingly so no loss of rigidity need to be feared.

In a heavy box vertical drill, a self-acting engagement of the automatic feed takes place as the drill reaches the work, and reversal of the travel first throws out the feed, and then pulls up the spindle. On another machine, a two-spindle elevating cross-rail type, a motor is mounted on each saddle with compact gear drive to its spindle. A third motor at the floor actuates the traverse of the table and the elevation of the cross rail, push-button control being arranged on the saddles.

Of the milling machines, two may be mentioned. One is an elaborate vertical-spindle miller with longitudinal feed of 72 in. and transverse of 33 in. It has a mass of mechanism to give 16 speed and feed changes, as well as a rapid table traverse at 150 in. per min. Feeds are interlocked, but both motions can be engaged simultaneously to produce diagonal movement. Traverse directions depend on into which of four positions a lever is thrown. Feeds are also applied to the circular table. The speed range has been devised to permit of the use of cutters with Widia-tipped blades. Another is a machine that has a table with an 8-ft traverse, but a single column to hold the arm and saddle. The latter is adjusted by hand, while the arm elevates through a 3-hp motor. The 3-in. spindle attains 1000 rpm at maximum. The cylinder, as well as all other shafts and certain gears, are mounted on anti-friction beds.

The remainder of the article deals with plano-millers and planing, gear-cutting, and grinding machines. A centerless grinder has the work feeding between opposed faces of two cup or ring wheels. The feed wheel is obliquely set in relation to the grinding wheel, and the dispositions are such that the points of contact between the respective wheels and the work are not opposite each other, consequently inaccurate stock does not tend to perpetuate its faults, but gradually becomes true. (*Machinery* (London), vol. 39, no. 1001, December 17, 1931, pp. 365–372, illus., *d*)

METALLURGY

A Direct Process of Iron Manufacture

ONE of the features of the process here described is that it is carried on at temperatures below the melting point of the metal. It is applied not only to iron but to such metals as tungsten, molybdenum, tantalum, and copper, as well as nickel, cobalt, vanadium, and chromium. The metals and alloys are obtained not in a liquid form but as finely pulverized metal accompanied by clay and silica in their original state.

Several reducing agents are used: hydrogen, illuminating gas, and alcohol, the latter after it has been decomposed into hydrogen and carbon monoxide in the presence of water vapor. If it is desired to obtain a pure metal, a pure oxide is used as the raw material and electrolytic hydrogen as the reducing agent; otherwise coke-oven gas and blast-furnace gas may be used, either in their original state or after being enriched with hydrogen.

The original article describes the continuous furnace used in this process. The furnace consists of an iron pipe 2.5 meters (98 in.) long and 50 mm (1.96 in.) in diameter. On the outside the pipe is covered by fireproof clay, over which is wound a chrome-nickel ribbon, and each turn covered by a layer of fireproof clay. The oven is heated electrically on the resistance principle. The cooler is at the side from which the reducing gas is supplied, while the oxides are charged from the opposite end. The oxides are charged in a crucible, which may be of iron but should preferably be of nickel, and is gradually moved forward. The duration of stay of each crucible in the oven does not exceed two hours. By means of such ovens the Moscow Electrozavod produces up to 300 kg (660 lb) a day of tungsten and molybdenum powder.

When iron ore is used, it is desirable to have it finely pulverized. The best method is to reduce it by gas reheated to 800 C. The gas that has not been used up in reduction is returned to the mains. No data as to the cost of the process or the consumption of gas are given. (L. P. Molkov, in the Russian publication, the *Industry Herald* (in Russian), vol. 11, no. 8, August, 1931, pp. 5–8, 1 fig., *d*)

MOTOR-CAR ENGINEERING

A Dual-Power Rear Axle

THIS name has been given to the vacuum-operated selective rear-axle gear installed on the new Auburn eight-cylinder and twelve-cylinder cars. It is manufactured by the Columbia Axle Company, a subsidiary of the Cord Corporation which owns control of the Auburn Automobile Company.

The axle has a floating gear driven by a spiral-bevel pinion in the conventional manner. Assembled within the ring gear on stub shafts are five planetary gears which mesh with and drive an internal gear secured to an extension of the differential carrier. The sun gear around which rotate the planetary gears is machined on a sleeve which is mounted free on the left axle shaft. This sleeve is splined on the outside so that it can be locked against rotation by a sliding-dog clutch member, splined to it and meshing with internal teeth machined on a differential housing flange. When it is locked in this manner the drive is taken by the ring gear from the pinion, the ring gear rotates, turning the planetary gears around the fixed sun gear, and the planetary gears in turn drive the internal gear on the differential carrier.

Differential idler gears are mounted on a cross-shaft through the differential carrier, and thus transmit the torque to the side gears and the axle shafts. In other words, under these conditions there is a double reduction, one through the ring gear and pinion, and one through the planetary gears to the internal gear. The overall ratio in this case is 5.0 to 1 on the eight and 4.5 to 1 on the twelve.

If it is desired to employ a direct drive, corresponding to a reduction of 3.5 to 1 on the eight and 3.0 to 1 on the twelve, the planetary reduction is locked out in the following manner:

The aforementioned sliding member is moved toward the ring gear so that internal teeth cut on the inner end of the sliding member engage teeth on the ring-gear hub. The sun gear in the planetary train is now no longer locked against movement with respect to the axle housing, but is locked to prevent movement with respect to the ring gear. In other words, it must turn with the ring gear, thus eliminating reduction through the planetary gears. The drive then is transmitted from the pinion to the ring gear, from the ring-gear hub to the sliding member, from this member to the sleeve carrying the sun gear, and through the planetary gears (which cannot rotate now) to the differential carrier.

The actual shifting from one ratio to another is accomplished by intake manifold vacuum, and is preselective in character. A vacuum cylinder, connected to the intake manifold, with a valve operated by the clutch pedal in the line, is mounted directly on the axle housing. The piston in this cylinder is connected to a rocker arm with a cam trip which shifts the

sliding member into engagement either with the teeth on the axle housing or with those on the ring gear.

The axle is designed to give an over-drive effect in "high high," and slightly more than normal acceleration with standard axle ratios in "low high." The speedometer-drive ratio is changed when the rear-axle gear is shifted. (Athel F. Denham in *Automotive Industries*, vol. 66, no. 2, Jan. 9, 1932, pp. 42–45 and 76, illustrated, *d*)

Carburetion of the Packard Twin-Six Car

IN THIS car the fuel system consists of a Stromberg duplex downdraft carburetor combined with an interesting downdraft intake manifold. Directly under the carburetor venturis are two conical "stoves" extending down into the exhaust manifold passages below the intake manifold. The manifold itself has three passages to each of the two blocks, each feeding two cylinders. The central passages are provided with baffles extending from top to bottom of the passage, with space for the inlet gases at either side. This baffle performs the function of preventing an over-rich mixture from reaching the center cylinders of each block. What it does is to trap the fuel that normally surges back and forth in a three-port manifold, which is the cause of this over-richness in six-cylinder blocks.

The trapped or surging liquid, as well as unvaporized fuel from the carburetor itself, drops down into the aforementioned stoves, where it is vaporized by exhaust heat. At the tip at the bottom of the cone there is located an atomizing jet with connection to the outside atmosphere. When the throttle is closed, air is sucked in through this jet at high velocity, causing atomization of the fuel lying in the bottom of the cone, for easy starting.

It must be understood that the intake air itself does not pass through these stoves, but over the top of the open end. The aforementioned atomizing jet is provided with a drain opening at the top, so that excess fuel in the intake stove will drain out below the engine pan. In this manner a virtually constant fuel level or reservoir is maintained at the bottom of the cone. The arrangement provides all advantages of an intake liquid-fuel heater, without heating the intake air itself, which would result in reduced volumetric efficiency. In fact, a 1-in. thickness of asbestos is inserted between the intake and exhaust manifolds where they bolt together, to reduce the flow heat from the latter to the former.

The angle between the blocks in the V is 67 deg. One of the reasons for the selection of this angle was the desire to eliminate the synchronous periods which occur frequently in multi-cylinder engines designed for equal firing intervals. (*Automotive Industries*, vol. 66, no. 2, Jan. 9, 1932, pp. 54–57 and 66, *d*)

POWER-PLANT ENGINEERING

Economic Generation of Process and Heating Steam

THE present article deals with economic steam conditions in industrial plants viewed from the low-pressure end. The author believes that the proper way is not to generate low-pressure steam for process work at low pressure or to reduce it to the required value by means of a reducing valve, but to utilize it first in an extraction engine or turbine or even a high-pressure engine and a turbine, and then utilize the residual heat for process work or heating.

The electric power is for the most part better generated by turbines, while mill and similar machinery, air compressors, and certain forms of pumping might well provide good conditions for an extraction engine. Where more or less constant heating load can be provided for by the exhaust steam from the engine without periods of blowing off to atmosphere, the conditions can well be met by a simple non-condensing pass-out engine, though an initial pressure of about 150 lb would be ample for the purpose. Where the two loads vary, one can either install a compound extraction engine or a heat accumulator.

As regards governing the engine, the author describes and illustrates an arrangement which applies to Galloways engines.

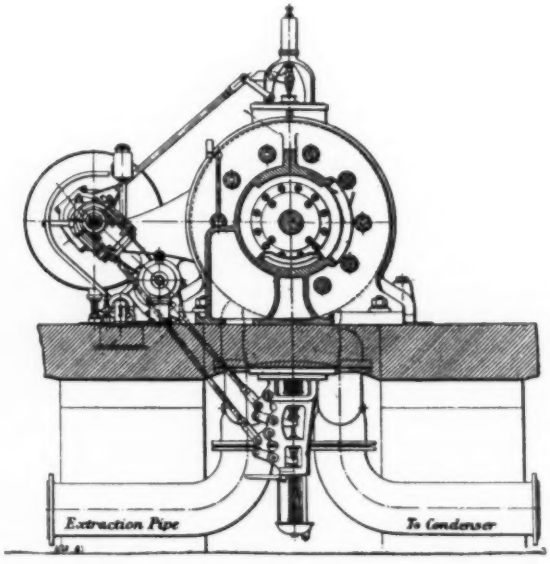

FIG. 6 STEAM ENGINE WITH DOUBLE-EXHAUST-VALVE ARRANGEMENT

Here the cut-off to the high-pressure cylinder is under the control of the speed governor, but to the low-pressure cylinder it is actuated by a regulator so as to maintain a constant pressure in the pass-out system. The regulation is said to be very sensitive.

Several attempts have been made to construct single-cylinder engines which will give the results obtained by the compound without its high first cost and the somewhat complicated dual governing system. This seems to have been more or less successfully accomplished by the Maschinenbau A.G. of Hirschberg, Silesia, in the shape of an engine with the double-exhaust-valve arrangement as shown in Fig. 6.

This is, as will be seen, a drop-valve bi-flow engine, its distinctive feature lying in the two exhaust valves. The lowermost of these valves opens into a pipe leading to the condenser, while the space between the two communicates with the extraction main by way of a non-return valve. While the upper exhaust opens with a lead of 10 per cent and closes 10 per cent in advance of dead center, the lower one has a variable cut-off and may even be kept closed during the whole of the exhaust stroke of the engine. Under such conditions, no steam can pass to the condenser.

This variable cut-off provides, however, for the whole range of extraction steam from 1 to 100 per cent of power steam, while the non-return valve precludes any of the steam in the extraction mains from flowing into the cylinder so as to guard against excessive compression. (F. Johnston Taylor in *Power House*, vol. 25, no. 11, Nov., 1931, first of a series of articles, pp. 53–55, 3 figs., *d*)

Turbine Expansion Lines of Actual Machines

THE expansion line is important in heat-balance and power-development studies. When steam is expanded in an ideal turbine the expansion line on a Mollier chart is vertical (at constant entropy). In a real turbine only part of the ideal heat drop is converted into mechanical work and the expansion line slopes to the right, the exact slope depending upon the efficiency of the turbine, which, among other things, is influenced by the moisture content of the steam. Before the days of the extraction cycle the turbine water rate was sufficient to give the necessary data for heat-balance studies. With the extraction turbine, additional data became necessary regarding the condition of the steam at various points between the throttle and condenser. Water rates in various turbines vary between wide limits, and the expansion line varies likewise. In the present article the author has collected and plotted data in two general groups, namely, industrial and central stations. Steepness of the expansion line indicates relative efficiencies, but not in a way that by itself would warrant comparison between machines without taking other factors into consideration. Some of the turbines were designed for extraction, some for no extraction, and some for gas reheat; some are for back-pressure operation, and some for condenser surface. In addition the data collected are not always comparable among themselves. In the two figures in the original article a variety of turbine types and sizes are represented, including single-expansion, tandem-compound, cross-compound, and steeple-compound, ranging from 1500 to 208,000 kw. The Benson boiler is included.

While the details presented in the article cannot be abstracted, attention is nevertheless called to the following excerpts dealing with pressures and temperatures:

"The Mollier chart clearly shows the reason for the statement often made that the central station is interested primarily in higher temperatures and the industrial plant in higher pressures. The central station is interested only in the power generated, and although superheat shows little theoretical advantage, practice proves that moisture seriously reduces turbine efficiency and increases maintenance. Practical considerations call for the expansion line as far to the right of the Mollier chart as possible.

"On the other hand, the industrial plant is interested primarily in back-pressure operation, with the exhaust conditions quite definitely fixed by industrial conditions. As a rule, high superheat in the exhaust is not desirable for industrial use but a low superheat of 10 to 20 deg (point *BB* on chart in original article) is often preferable to wet steam. Assume steam at 85 lb, 20 F superheat is desired, and the electrical and steam loads show they would balance at a water rate of 25.3 lb per kw or (with 90 per cent mechanical and electrical efficiency) a heat extraction of 150 Btu per lb of steam.

"With a turbine expansion line along *AA-BB* the initial pressure conditions would be fixed at about 580 lb, 690 F. If less power were needed, a lower pressure and temperature could be used. Increasing the temperature only would throw the expansion line to the right, increase the superheat in the exhaust, and give no increase in power. If more power is needed, a further increase (along the line *AA-BB*) in both pressure and temperature is needed, and for the range of usual industrial process-steam requirements, this increase gets into the unexplored pressure region as quick as, if not more quickly than, it does into the unknown temperature region. If wet steam is permissible, the expansion line is thrown to the left, and this also means an increase in pressure. European Benson and Loeffler plants, successfully operating, cover this higher pressure range up to 2500 lb, 850 F." (*Power Plant Engineering*, vol. 35, no. 23, Dec. 1, 1931, pp. 1141–1144, 2 figs., *cA*)

Operating Results in a British Central Station

THIS station, the Deptford West, is one of the plants of the London Power Company. The article describes the station in detail and tells of the methods used in testing. The plant consists of five turbo-alternators, two of 25,000 kw installed in 1929, two of 35,000 kw added during 1930, and a third unit of the same output placed in operation recently.

During the first complete twelve months in operation 280,875,110 kwhr were generated at an average fuel consumption of 1.31 lb per kwhr, the maximum load being 76,000 kw, the load factor 41.837 per cent, and the thermal efficiency 23.188 per cent. These results were obtained in spite of the initial troubles, some of which the article describes.

No difficulty was experienced in burning coke so long as the amount fired did not exceed 20 per cent of the total. There were no indications of increased wear on the grates, but there were several grate failures due to faulty air distribution. Fitting expanded-metal baffles in the compartments has not completely overcome this trouble.

In this connection it may be pointed out that Deptford West is the first stoker-fired station in which water-cooled furnaces have been used throughout, and that, as tests made at Willesden have shown, complete exposure of the wall tubes and the use of high-volatile fuels considerably reduce the furnace temperature and increase the tendency to incomplete combustion. The uncovered portion of each side wall was therefore reduced to 56 per cent, the rear wall completely enclosed in refractory, and the water-tube surface exposed to direct radiation limited. The temperature of the refractory was therefore beneficially reduced, and after a time its fusion was arrested and little further wastage occurred. The tubes act as a support, and so far the limit of the life of the lining as a whole has not been reached. Some trouble was experienced with the side-wall refractories near the end of the arch, where the thin layer over the tubes was rapidly eroded, but an adjustment in the composition of the refractory has effected a definite improvement. In the larger boilers, however, the first wall tube is 18 in. from the end of the arch, an arrangement which has given rise to little trouble in this respect. The tubes of the water-cooled arches are fed from the main steam and water drums of the boiler, with local recirculation. The refractory blocks were fitted to, and supported by, the tubes and showed a tendency to spall from the faces of the latter. This has been largely corrected by the use of carborundum paste between the arch and the tubes. Experience has also shown that the exposure of the lower face of the tube is not detrimental to satisfactory combustion, and so far no renewal has been necessary.

Considerable trouble was experienced with leakage in the economizer tubes, principally near the feed outlet, said to be due to shrinkage of tubes in the header seatings due to improper heating. This has been overcome by using dampers to bypass the economizers while the pressure is being raised, thus maintaining the temperature rise and fall at a reasonable figure. There was also trouble with excessive leakage at the expanded joints in some of the superheaters. Means are described by which it was eliminated.

The results obtained are the more noteworthy as the fuel used is not of particularly high calorific value. The fuel fired per square foot of grate area varied from 36.2 lb to 21.4 lb per hr, the forced draft being from 0.8 in. to 1.6 in. water gage. This gave an evaporation of from 6.9 lb to 6.64 lb per sq ft of heating surface. Improvements over the first year's

working were also obtained by reducing the feed-pump discharge pressure during the last three months of the year, thus decreasing the amount of electricity used in the works.

A large share of the power used inside the plant is supplied from house sets.

Figures given in the original article show, among other things, variations in the steam pressure and temperature, the vacuum, feedwater temperature, and the factors which affect the boiler efficiency. The ash content of the fuel lies between 8 per cent and 11 per cent, and is very little affected by the proportion of coke. The average evaporation was about 85 per cent, or very close to the main economical rating. The actual normal blowdown is negligible, and make-up is principally required to make good leakages of steam and water from the glands and safety valves.

The original article gives the results of a station performance test which was carried out for a period of 8 hr in 1931. The fuel consumption during this test was 193.45 tons of coal and 49.7 tons of coke, the calorific values being 11,529 and 9672 Btu per lb, respectively, or an average of 11,150 Btu. Of this total of 544,656 lb of fuel, 4000 lb were recovered as riddlings, their calorific value being 6390 Btu. The six boilers used were steamed at as near their normal rating as possible, and at a load factor of 99.47 per cent, the boiler-room operating factor being 95.2 per cent. The water evaporated was 7.727 lb per lb of fuel, giving a boiler efficiency of 82.35 per cent. The steam conditions at the stop valves of the two turbines were 371.4 lb per sq in. and 776 F, the heat consumed per kwhr generated and sent out being 13,320 Btu and 13,770 Btu, respectively, while the steam consumption was 9.026 lb per kwhr generated.

The turbine-room efficiency was 31.11 per cent, and its operating factor 99.48 per cent, the resulting overall thermal efficiency and operating factor being 25.62 per cent, and 94.7 per cent, respectively. (*Engineering*, vol. 133, nos. 3445 and 3447, Jan. 22 and Feb. 5, 1932, pp. 89–91 and 150–153, 33 figs., *e*)

SPECIAL PROCESSES

Atomization and Fatigue of Thin Coatings of White Metal Deposited on Mild-Steel Surfaces

THE cracking of white-metaled bearings under service conditions and the possibility of improving the fatigue strength of the white metal have been investigated at the National Physical Laboratory to find the effect of composition and method of application on the adhesion and fatigue of such coatings.

Rings of S. 14 mild steel 3 in. in external diameter, 1.5 in. long, and 0.15 in. thick were lined with white metal to a thickness of 0.02 in. by various makers and were subjected to a predetermined cycle of bending stress at a frequency of 3000 per min. No attempt was made to introduce a frictional resistance at the surface of the white metal, but to imitate the conditions of practice the tests were made at a temperature of approximately 120 C, and the surface of the white metal was covered with oil. Tests were also made on steel rings lined with lead bronze.

At various stages of the test the liner was examined and the progress of the cracks noted. The initial adhesion of the white metal to the steel was also measured by a method specially devised for the purpose. Comparison of the behavior of (1) cast and (2) centrifuged white-metal liners was also made, and the distribution of the constituents of the white metal due to centrifuging was investigated.

The tests of the strength of the static adhesion of the white metal to the steel indicated that in the best practice the adhesion was fully equal to the ultimate shear stress of the white metal.

Under long-continued alteration of stress within the fatigue limit of the steel to which the white metal was attached, the surface of the latter rapidly became covered with a network of cracks, and in all the methods and materials tested, with the exception of the lead bronze, its adhesion to the steel was ultimately destroyed. In the best practice it was found that the complete destruction of the adhesion was only effected when the stress was a large fraction of the limiting fatigue stress of the steel and the number of repetitions of the order of 15 million.

In the case of the steel rings lined with lead bronze, no apparent deterioration in adhesion and comparatively insignificant fatigue cracking of the liner were apparent after 15 million cycles of stress at a range of 18.9 tons per sq in. It was clear that in both respects the merits of this alloy were of an entirely different order from those of the other so-called white metals. A very complete series of comparative tests in the N.P.L. journal-friction testing machine at high loads (up to 2500 lb per sq in.) and with various lubricants indicated a performance of the lead bronze under forced lubrication and with continuous rotation that was fully equal to that obtained from one of the best tin-base alloys. (T. E. Stanton in *Reports and Memoranda, Air Ministry, no. 1424 (M 74)* December, 1930, 8 pp. and 2 diagrams, *d*)

STEAM ENGINEERING (See also Thermodynamics: Thermal Properties of Water in the Region from 10 C to 500 C, and at Saturation Pressures up to 300 Atmospheres)

Experiments on the Process of Evaporation

THE process of steam formation is usually considered to be so simple that few people bother with it any more. The present authors were led to undertake certain experiments as a result of observations made in earlier ones dealing with the heat of evaporation of water at higher pressures. In these tests it was found that the temperature of the water was higher than that of the steam. In particular, it was found that at 270 C (56 atm pressure) the difference in temperature between the two increases with the amount of water already evaporated, or with the fall of the water level. From measurements of pressure simultaneously carried out it was found that the steam always has the temperature of saturation, which means that the water must be superheated.

In the case of thermodynamic equilibrium between the liquid and gaseous phases of a homogeneous substance there must obtain at each point throughout the entire system the vapor pressure p and the vapor temperature T. The mass relation of the two phases does not matter. On the other hand, there must be equilibrium of masses as well, which means that the same number of molecules must pass through the surface separating the two phases from the liquid to the vapor as go the other way. As in the case of a steam boiler, however, as soon as more water is evaporated than steam is condensed ("steam generation"), a unidirectional transfer of mass takes place, with the result that the state of thermodynamic equilibrium is destroyed.

Among the factors affecting the process of evaporation, the authors mention evaporation in the case of thermodynamic equilibrium. Here the equation of state of the system must include, in addition to p and T, the variable representing the

surface O which is being changed by the formation of the bubbles of steam. In this connection the authors show that a small steam bubble of pressure p_d is in a state of equilibrium with the expanded liquid around it only in the case when the temperature common to both steam and liquid is higher than the saturation temperature at the liquid pressure p_f for a plane surface.

The authors present two equations (one derived from Lord Kelvin's work), by virtue of which $p_d - p_f$, and hence the superheat of the liquid as compared with its normal state, must be the greater the smaller the bubbles of steam, which leads to the remarkable conclusion that in an expanded liquid space a steam bubble cannot generate spontaneously. If, however, in the liquid or along the walls of the containing vessel there are present curved surfaces, such as bubbles of foreign gas, tuberculations, etc., steam can form—for example, by the evaporation of the water, the bubbles of foreign gas acting as "nuclei of evaporation," the superheat of the water being thereby correspondingly reduced.

Other factors affecting evaporation are the influence of the walls and flow, and steam generation. With this latter present there can be no state of equilibrium, since at some place or other, new, very small bubbles are created and rapidly move away. If at a given particular place, nuclei of evaporation should be absent, a constant superheat in that immediate region may be considered as possible. The steam, however, is still generated at saturation temperature. As the bubbles rise rapidly there can be no complete equalization of temperature between the water and the steam, and the superheat of the liquid is here a function of the number of nuclei of evaporation present and the height of the level of the liquid. This view is tied in with the theory of evaporation developed some time ago by Bošnjakovič.

The experiments carried out, which included those on the transfer of heat in the case of smooth and rough surfaces, lead the authors to the conclusion that the water being evaporated is always superheated as compared with the steam, the latter having the temperature of saturation. The superheat is particularly great in the boundary layer next to the heated surface. The influences of the height of water level and the rate of evaporation have been carefully determined in order to test the theory of Bošnjakovič, and experiments would indicate that the latter is still incomplete.

The coefficient of heat transfer in the case of smooth surfaces increases from about $\alpha \approx 650$ to $\alpha \approx 4000$ kg-cal per sq m per hr per deg C difference of temperature for thermal loads of $H = 250$ to $H = 43{,}000$ kg-cal per sq m. The variation of the coefficient of heat transfer for values above $H = 2000$ is practically along a straight line. The heat transfer in the case of rough surfaces is not quite uniform, and in the case of very rough surfaces is extremely variable. This apparently has some relation to the number of gas particles adsorbed by the surface. The coefficient of heat transfer in such a case may become as high as $\alpha = 14{,}000$ kg-cal per sq m per hr per deg C difference of temperature. One part of the article, which cannot be abstracted because of lack of space, deals with the relation between the process of evaporation on the one hand, and the transfer of heat between the heating surfaces and the water on the other. (M. Jakob and W. Fritz in *Forschung auf dem Gebiete des Ingenieurwesens*, vol. 2, no. 12, issue A, December, 1931, pp. 435–447, 24 figs., *eA*)

TESTING AND MEASUREMENTS (See Hydraulics: The Grid-Constricted Orifice)

THERMODYNAMICS (See also Steam Engineering: Experiments on the Process of Evaporation)

Thermal Properties of Water in the Region From 10 C to 500 C, and at Saturation Pressures up to 300 Atmospheres

THE majority of investigations dealing with thermal properties of water refer really to steam, i.e., the gaseous phase, or else deal with both phases, along the saturation line. As hot water at high pressures has come recently into use in the industries, it becomes necessary to determine its thermal properties under the conditions mentioned in the title. The present investigation has been carried out by one of the authors in the Thermodynamic Laboratory of the I. G. Dye Industries in Oppau, and in part repeated at the Physico-Chemical Institute of the University of Heidelberg. From the measurements of specific volume of liquid water at constant pressure and rising temperatures, tables have been computed for the heat content and specific heat of water. As the heat content had also been measured under similar conditions, the results of calculation could be compared with those of observation. In the region above the critical temperature where calculation could no longer be employed with sufficient certainty, the heat content was determined only experimentally.

In the course of these experiments the specific volumes of liquid water were determined for pressures between 150 and 300 atm and temperatures from 10 C to 370 C, with a precision below the critical temperature of from ± 0.2 to ± 0.4 per cent, and above the critical temperature of 2 to 4 per cent. Simultaneously the heat contents of water and steam in the same range of pressures between 10 C to 500 C were determined with a precision of ± 3 per cent. By smoothing out the curve for the specific volume and interpolating between the values of the International Skeleton Tables and the experimentally determined values, the product of the Thomson-Joule effect $\times$ specific heat, the heat content, and the specific heat at constant pressure were determined.

The product of the Thomson-Joule effect $\times$ the specific heat, and hence the Thomson-Joule effect itself, decreases greatly with the increase of temperature from initially positive to finally large negative values. The product crosses the zero line at a temperature the location of which depends somewhat on the pressure. The differential quotient of the effect as a function of pressure increases from initially small negative values to ultimately large positive values. The zero point in this variation within the range of precision of the experimental values does not appear to depend on the pressure, and lies somewhere around 52 C.

The specific heat of liquid water falls off at all temperatures with increase of pressure. In the steam range, contrariwise, it increases with the pressure. The isobars of the specific heat in the c_p-t diagram have a maximum value of c_p which below the critical pressure is located at the corresponding boiling point, but above the critical pressure is found at a much higher temperature but has a lower numerical value. (Max Trautz and Hans Steyer in *Forschung auf dem Gebiete des Ingenieurwesens*, vol. 2, February, 1931, pp. 45–52, 9 figs., *eA*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive, *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

The Basic Laws of Heat Transmission

(*Continued from page 279*)

TABLE 6 CONDUCTIVITIES OF GASES AND VAPORS AT 32 F

	k	a	C
Air	0.163	0.00165	225
Ammonia	0.149	0.0028	...
Argon	0.110	.....	...
Benzene	0.057	.....	...
Carbon dioxide	0.097	0.0021	...
Carbon monoxide	0.155	0.0017	281
Chlorine	0.053	.....	...
Ethane	0.126	0.0036	...
Helium	0.970	.....	59.4
N-Hexane	0.085	0.0032	...
Hydrogen	1.130	0.0015	169
Methane	0.210	0.0027	...
Neon	0.031	.....	45
Nitrogen	0.163	0.0016	206
Nitrous oxide	0.100	.....	...
Oxygen	0.165	0.0016	215
Steam	0.117	0.00217	...
Sulphur dioxide	0.056	.....	...

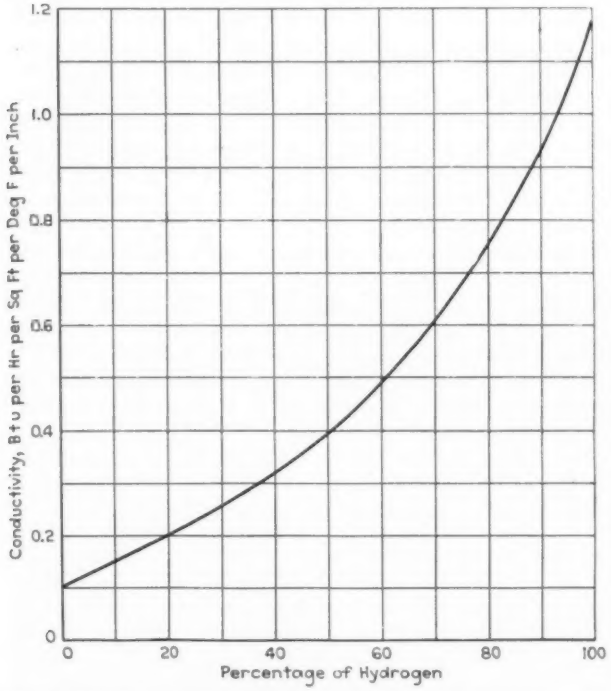

FIG. 6 THERMAL CONDUCTIVITY OF MIXTURES OF HYDROGEN AND CARBON DIOXIDE

(Ibbs and Hirst, Proc. Roy. Soc., vol. 123 (1929), p. 134.)

Fig. 6 shows a typical curve for the conductivity of a mixture of two gases in various proportions, from the data of Ibbs and Hirst.[24] In a few cases a mixture of two gases may have a higher conductivity than either gas alone.[25]

It would be hardly feasible to acknowledge here all of the sources of information which were used in preparing the foregoing material, inasmuch as some four hundred papers and texts were consulted. Every effort was made to obtain the most complete and reliable data published to date, and in most cases the figures quoted are weighted averages based on a careful study of the methods and technique of each investigator. Any criticisms or suggestions bearing on this subject would be welcomed by the author.

[24] T. L. Ibbs and A. A. Hirst, Proc. Roy. Soc., vol. 123 (1929), p. 134.
[25] H. Schmick. *Phys. Zeit.*, vol. 29 (1928), p. 633.

The following additional works on the general subject of Heat Conduction are particularly recommended for reference:

"Theory of Heat." Thos. Preston. 4th Ed., Macmillan Co., London and N. Y., 1929.
"Principles of Chemical Engineering." Walker, Lewis, and McAdams. 2nd Ed., McGraw-Hill, N. Y., 1927.
"Der industrielle Wärmeübergang." A. Schack. Verlag Stahleisen, Düsseldorf, 1929.
"Die Wärmeübertragung." M. ten Bosch. J. Springer, Berlin, 1927.
"Der Wärme- und Kälteschutz in der Industrie." J. S. Cammerer. J. Springer, Berlin, 1928.
"Einführung in die Lehre von der Wärmeübertragung." H. Gröber. J. Springer, Berlin, 1926.
"A Survey of Heat Conduction Problems." E. Griffiths. Proc. Phys. Soc. (Lond.), vol. 41 (1928), p. 151.
"International Critical Tables." Vol. 5.

Engineering, Investment, and Social Well-Being

(*Continued from page 255*)

one of them. Others are: application of improvements in production to lessened prices rather than to increased profits; a shortening of working hours without decrease of real wages; more definitive and drastic "blue sky" laws, applicable to investment operations hitherto considered quite respectable; the diversion of uninvestable profits through benevolence or by income taxation to expenditure for social purposes; etc., etc. Most of these proposals will operate by diminishing excessive savings and increasing consumption; but in addition we must keep savings out of harmful activities and confine them to their normal and useful applications in new investment.

This latter process is preeminently the function of the engineer. It is his business to discover and develop all possible opportunities for profitable new investment. In the light of the rudimentary but fundamental analysis made above, almost the whole burden of finance and investment rests on his shoulders, for all of the activities which begin and end in the financial field have proved to be, and evidently are, false and destructive.

This dependence of the financial structure on the engineer will become more definite as time goes on. The easy and obvious fields for investment are being worked out. The rate of increase of population is slowing up, natural resources are being thoroughly explored and exploited, the whole mechanism of an industrial civilization is approaching completion. And the time will again descend upon us—doubt it not!—when a flood of savings will seek profitable investment.

When that time comes we may hope that the guardians of our money and credit will have attained a new wisdom, imparted to or derived from the clients who provide their resources. Only actual investment will be sought, and only expert advice will serve to find it. We may even in that day, to paraphrase an obscure passage of scripture, see seven bankers taking hold on one engineer, saying, "Come with us."

So let it be! For such is the importance of engineering and engineering research to the investment market, and to the general prosperity of the country as well.

SYNOPSES OF A.S.M.E. PAPERS

THE papers abstracted on this and following pages appear in the current issues of the Applied Mechanics, Fuels and Steam Power, and Railroad sections of A.S.M.E. Transactions. These sections have been sent to all who registered in the similarly named Divisions. Other sections are in the course of preparation and will be announced, when completed, in later issues of "Mechanical Engineering." Copies of these papers may be obtained by those not registered in these Divisions by addressing the Secretary of the A.S.M.E., 29 West 39th Street, New York, N. Y.

APPLIED MECHANICS

The Hydraulic Jump and Related Phenomena

IN THIS paper the author presents certain results which were obtained by him in studying the hydraulic jump over a period of years. A general characteristic of the "state" of flow is introduced through the notion of "kineticity of flow," expressed numerically by a "kinetic flow factor." The fundamental relations, referring to the jump, are presented in generalized form. A physical basis is offered to explain the different forms in which the jump occurs. The important practical cases of a jump below a sluice and at the foot of a weir are studied in detail. Formulas are devised and charts given which make it possible to solve different problems of engineering practice. (Paper No. APM-54-1, by Boris A. Bakhmeteff.)

Analysis of Stresses in Circular Plates and Rings

WHILE the fundamental theory for calculating stresses in circular plates is well known, it has not been employed generally by engineers because of its complexity. In the present paper the authors present a simplified method for calculating the stresses in flat, circular plates, with or without a hole in the center, the loads being applied in any manner provided they are uniformly distributed in circles concentric with the edges. They also discuss the stresses in a hollow cylinder having rigidly attached flat heads, and give a method of calculating stresses in cylinders with rigidly attached flanges. (Paper No. APM-54-2, by E. O. Holmberg and Karl Axelson.)

The Boundary Layer and Skin Friction for a Figure of Revolution

THE boundary-layer equations for a figure of revolution are first derived in the Prandtl form. These are then integrated to give the so-called "integral relation" for the case in question. Power-series expressions for the boundary-layer profiles in laminar and turbulent flow are assumed and substituted into the integral relation. In this way expressions are obtained for the boundary-layer thickness and for the contribution to the skin friction of the laminar and turbulent portions of the boundary layer. In particular a simple expression is given for the boundary-layer thickness at the stagnation point, which is a singular point of the equation. Conditions at the point where the boundary-layer flow changes from laminar to turbulent are discussed in some detail, and the simple Prandtl assumption for the transition-point behavior is adopted as the basis of the further calculations. Numerical values for the N.P.L. International Airship Model are introduced, and theoretical curves are given for the resistance coefficient as a function of the Reynolds number. These are compared with previous theoretical results and with experimental values.

The agreement of the theory with experiment is considered satisfactory in view of the assumptions which had to be introduced into the analysis in order to supplement the present state of knowledge concerning boundary-layer phenomena. The general integral relation developed in the paper can be used to obtain more accurate results in the future, when more is known regarding boundary-layer profiles in curved and diverging (or converging) flows. (Paper No. APM-54-3, by Clark B. Millikan.)

On the Subcritical Speeds of the Rotating Shaft

DISTURBANCES sometimes encountered at speeds above the fundamental whirling speed, having the fundamental frequency, are usually, and correctly, attributed to internal friction. Other disturbances frequently met with at speeds below the fundamental whirling speed, and when the motions also have the fundamental natural frequency, have been thought to be due to minute variations of the angular velocity of rotation caused by the eccentric application of gravity. The present paper discusses the latter group of phenomena, and aims to show that the cause assigned is incorrect. (Paper No. APM-54-4, by C. Richard Soderberg.)

The Strength of Thin Plates in Compression

THE stability of thin plates has been investigated by many authors. However, in aeronautical structures, thin metal sheets are often used beyond the stability limits, and the load which can be carried by the structure is determined by the ultimate strength in compression. A recent series of experiments by the Bureau of Standards showed the ultimate load to be independent of the width and length of a plate and approximately proportional to the square of the thickness. In the present paper an approximate theoretical analysis of this problem is developed, by which the "effective width" and the ultimate strength can be found. The result of this analysis shows the ultimate strength of a plate to be proportional to the square roots of the modulus of elasticity and the yield point of the material, and to the square of the thickness. This result gives a good check with the experiments mentioned. (Paper No. APM-54-5, by Theodor von Kármán, Ernest E. Sechler, and L. H. Donnell.)

FUELS AND STEAM POWER

Slag-Tap Furnaces

IN THIS paper the molten-slag-tap furnace is followed from its original application to a power-plant boiler and brought up to date. The troubles which have developed in operating large furnaces with this type of ash removal are discussed, with the remedies applied. A comparison is made between similar boilers equipped with a hopper bottom and a slag

bottom, and some experimental data are given. (Paper No. FSP-54-1, by A. L. Baker.)

Design Features and Operating Results of Fairfield Blast-Furnace Power Plant

THIS paper discusses one of the latest blast-furnace power plants, built at the Fairfield steel plant of the Tennessee Coal, Iron & Railroad Company, and shows that by the improvement in efficiency in general it is possible to increase the electric power generated from surplus blast-furnace gas per ton of product about 50 per cent over what was average practice nine years ago, this result being due to increased efficiency of boiler plant, as well as to the increased amount of blast-furnace gas available. The operating results for a week's period are given, as well as descriptions of the automatic combustion control employed, the system of utilizing surplus steam from an adjacent plant, the method of handling water systems, and other unusual features. (Paper No. FSP-54-2, by F. G. Cutler.)

Conversion of Coal-Fired Boilers and Furnaces to Gas Firing

THIS paper deals with the use of natural gas in Memphis, Tennessee, the methods and data used in making estimates of gas consumption, the application of the degree-day to this end, and the actual operating data for various types of plants converted to gas fuel. (Paper No. FSP-54-3, by William D. Edwards.)

Recent Developments in By-Products From Bituminous Coal

AFTER pointing out that the by-product oven has displaced the beehive oven as a producer of metallurgical coke, the author discusses the increasing value of by-products as compared with that of the coke itself. He then takes up successively the subjects of competitive sources of gas for industrial and domestic use; utilization of the hydrogen in coke-oven gas for the production of synthetic ammonia; competition between synthetic and by-product ammonia; utilization of sulphur in coke-oven gas in the production of ammonium sulphate; processes for the recovery of sulphur in connection with gas purification; recovery of phenols from ammonia-still wastes; benzol and light oils; production of resins from coal by-products; tar and tar products; and the hydrogenation of coal tar. (Paper No. FSP-54-4, by A. C. Fieldner.)

Grindability of Coal

THIS paper points out the need for a method of determining the grindability of coal and outlines a method by which a prepared sample is partly pulverized and the new surface produced is measured in accordance with Rittinger's law. Two types of grindability machines, the mortar and pestle and the ball mill, are described, and test data obtained from both types are compared. The relation between pulverizer capacity and grindability is discussed. A representative list of the coals of the United States and Canada is presented showing their grindabilities and the relation between grindability and volatile content. The relation between the grindability of petroleum coke and its method of manufacture and volatile content is discussed. (Paper No. FSP-54-5, by R. M. Hardgrove.)

Burning Oil-Refinery Waste Fuels in a Modern Steam Plant

UNSALABLE by-products in the refining of crude petroleum present a disposal problem. Such undesirable by-products are the acid and alkaline sludges and acid tar, the residues from the purification of lubricating oils and gasoline by the use of sulphuric acid, and the fine coke, or breeze, screened from the salable lump petroleum coke. Refineries were forced to burn the sludges to effect their removal. The chief problem was to get them into condition to be pumped. Louisiana Steam Products, Inc., entered into contract with a large refinery to supply their steam and electric requirements from a plant that would burn non-merchantable refinery waste fuels up to 50 per cent of the total heat content of the fuel required. The equipment used in this installation is described. (Paper No. FSP-54-6, by H. J. Klotz.)

Pulverization and Boiler Performance

WHILE much has been said about the effect of varying degrees of pulverization, this paper gives specific and practical information on the relationship of pulverization of coal to boiler performance. The paper contains a résumé of theoretical studies and actual tests that have been made in the past by other investigators, and a recapitulation of the factors and theory of effect of fineness of grind on the combustion of pulverized coal and design of furnaces, mills, and boiler arrangements. Results are given of efficiency tests made at Cahokia station, St. Louis, with various finenesses. (Paper No. FSP-54-7, by E. H. Tenney.)

RAILROADS

Practical Application of Alloy Steels to Locomotives

IN THE critical railroad situation, methods for reducing costs are important. The reduction of locomotive-maintenance costs by the judicious use of new ferrous-metal products is advised—those very products developed by steel-mill research for the industries aided by the railroads. The best of engineering practice should be applied to the design of built-up assemblies that will realize maximum strength and will reduce wear and tear of joinings, such as the integral bed frame for the locomotive foundation. The high initial cost of using nitrided steel and other special materials, as advocated in the paper, is expected to be justified by the reduced costs of maintenance and loss of service of locomotives. An accounting system should, if necessary, be developed by which the cost of repairs or replacements can be recorded for easy reference. In conclusion, the author emphasizes the great possibilities in design, as the selection of steels to cure all evils is only a portion of the problem. (Paper No. RR-53-1, by C. E. Barba.)

Metallurgy in the Railroad Field

THE alleged conservatism of the railroads toward changes in the materials going into equipment is explained by their strict adherence to a safety-first policy. The subject-matter of the paper is discussed under three main headings of manufacturing methods, materials, and specifications. It is pointed out that, in order to improve a given part, changes in design should be considered which would minimize the chances for defects due to improper or improperly controlled manufacturing practices. Next, a plea is made for better steel-mill practice, closer control, and better inspection. After all these points have been considered, further increases in strength and ductility can be obtained through the use of alloying elements. Attention is given to the steps taken in improving some parts which have previously been a source of serious concern to the railroads. (Paper No. RR-53-2, by A. E. White.)

REVISIONS AND ADDENDA TO THE BOILER CONSTRUCTION CODE

IT IS THE policy of the Boiler Code Committee to receive and consider as promptly as possible any desired revision of the Rules and its Codes. Any suggestions for revisions or modifications that are approved by the Committee will be recommended for addenda to the Code, to be included later on in the proper place in the Code.

The following proposed revisions have been approved for publication as addenda to the Code. They are published below with the corresponding paragraph numbers to identify their locations in the various sections of the Code, and are submitted for criticisms and approval from any one interested therein. Communications should reach the Secretary of the Boiler Code Committee, 29 West 39th Street, New York, N. Y., in order that they may be presented to the Committee for consideration.

PAR. P-2 REVISED:

P-2. *a* Steel plates for any part of a boiler subject to pressure and exposed to the fire or products of combustion shall be of firebox quality in accordance with Specifications S-1 or S-2.

b Steel plates for any part of a boiler subject to pressure and not exposed to the fire or products of combustion shall be of firebox or flange quality in accordance with Specifications S-1 or S-2.

c Minimum tensile-strength limits other than those specified for flange and firebox plates may be used provided a range of 10,000 lb per sq in. is specified, that the maximum limit does not exceed 65,000 lb per sq in., and that the steel conforms in all other respects to Specifications S-1 and S-2.

d Seamless steel drum forgings made in accordance with Specifications S-4 may be used for any part of a boiler for which firebox quality only is specified, or for which either firebox or flange quality is permitted.

PAR. P-3. REVISED:

P-3. Open-hearth-steel pipe or steel tubing in accordance with Specifications S-18 or S-17 may be used for a boiler drum or other pressure part exposed to the fire or products of combustion, provided the nominal diameter of the pipe or tubing is not greater than 18 in.

PAR. P-9. DELETE SECOND SENTENCE OF SECOND SECTION OF THIS PARAGRAPH.

PAR. P-21. REVISED:

P-21. Generating tubes for boilers expanded into tube seats shall comply with Specifications S-17 for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes, or Specifications S-22 for Seamless Copper Boiler Tubes.

Open-hearth-steel pipe or wrought-iron pipe, not to exceed $1\frac{1}{2}$ in. pipe size, which meets the Specifications for Steel or Wrought-Iron Pipe, may be used for water-tube boilers for a working pressure not to exceed 250 lb per sq in., when screwed in the sheet or fittings, provided the wall thickness is at least 50 per cent greater than the minimum wall thickness required by Table P-2 or P-3.

PAR. P-22. REVISED:

P-22. The maximum allowable working pressures for steel or wrought-iron tubes or nipples used in water-tube boilers shall be as given in Table P-2 or P-3. The minimum thicknesses of tubes used in fire-tube boilers, for various maximum allowable working pressures, shall be as given in Table P-5.

The maximum allowable working pressure for copper tubes or nipples used in water-tube or fire-tube boilers, shall be as given in Table P-4, but they shall not be used for pressures exceeding 250 lb per sq in. nor for temperatures exceeding 406 F.

TABLES P-2, P-3, AND P-5. ADD THE WORDS:

"Conforming to the Requirements of Specifications S-17," to the titles of these tables.

TABLE P-4. ADD THE WORDS:

"Conforming to the Requirements of Specifications S-22," to the title of this table.

PAR. P-25. ADD FOLLOWING SENTENCE:

Galvanized pipe shall not be used.

PAR. P-186. ADD FOLLOWING SENTENCE TO THIRD SECTION OF THIS PARAGRAPH:

Furnaces subjected to compression stresses may be fusion-welded provided the welds are stress-relieved in accordance with Par. P-108 and bend tests of at least one sample for each furnace of the welding used meet the requirements of Par. P-102.

PAR. P-273. INSERT THE FOLLOWING AS SECOND SENTENCE OF THIS PARAGRAPH:

The maximum allowable pressure at which the safety valve may be operated shall be cast or stamped on the body of the valve.

PAR. P-288. REVISED:

P-288. *a* Every attached superheater shall have one or more safety valves near the outlet. The discharge capacity of the safety valve, or valves, on an attached superheater may be included in determining the number and size of the safety valves for the boiler, provided there are no intervening valves between the superheater, safety valve, and the boiler, and provided the discharge capacity of the safety valve or valves on the boiler, as distinct from the superheater, is at least 75 per cent of the aggregate valve capacity required.

b Every independently fired superheater shall have one or more safety valves having a discharge capacity based on Par. P-270, provided that valves are fitted which permit the superheater to become a fired pressure vessel. If communication between the superheater and the boiler cannot be closed, safety valves shall be provided as prescribed in Par. P-288*a*.

c A soot-blower connection may be attached to the same outlet from the superheater that is used for the safety-connection.

PAR. P-296. REVISE FIRST SENTENCE OF SECOND SECTION TO READ:

Where the use of a pipe longer than 10 ft becomes necessary, an exception may be made to the rule that the gage must be arranged so that it cannot be shut off except by a cock placed near the gage, and a shut-off valve or cock arranged so that it can be locked or sealed open may be used near the boiler.

PAR. P-303. REVISED:

P-303. When boilers are connected to a common steam main, the steam connection from each boiler having a manhole opening shall be fitted with two stop valves having an ample free-blow drain between them. The discharge of this drain valve must be visible to the operator while manipulating the valve. The stop valves shall consist preferably of one automatic non-return valve (set next the boiler) and a second valve of the outside-screw-and-yoke type; or, two valves of the outside-screw-and-yoke type shall be used.

PAR. P-308. REVISED:

P-308. Each boiler shall have a bottom blow-off pipe fitted with a valve or cock in direct connection with the lowest water space practicable.

The minimum size of pipe and fittings shall be 1 in., and the maximum size shall be $2^1/_2$ in., except that for boilers with 100 sq ft of heating surface or less, the minimum size of pipe and fittings may be $^3/_4$ in.

Straight-run globe valves of the ordinary type as shown in Fig. P-23, or valves of such type that dams or pockets can exist for the collection of sediment, shall not be used on such connections.

Straight-way "Y"-type globe or angle valves may be used in vertical pipes, or they may be used in horizontal runs of piping provided they are so constructed or installed that the lowest edge of the opening through the seat shall be at least 25 per cent of the pipe diameter below the center line of the valve.

Return connections of the same size or larger than the size herein specified may be used, and the blow-off may be connected to them. In such case the blow-off must be so located that the connection may be completely drained.

All water walls or water screens forming parts of a steam boiler shall be equipped with drain or blow-off valves conforming to the requirements of this paragraph and Par. P-311 for boilers.

PAR. P-310. ADD FOLLOWING SENTENCE:

Galvanized pipe shall not be used.

PAR. P-311*a*. ADD FOLLOWING SENTENCE:

The drain or blow-off valves for water walls or water screens forming parts of a boiler shall conform to the requirements of this paragraph and also of Par. P-308.

PAR. P-314. REVISED:

P-314. *Feed Piping.* The feedwater shall be introduced into a boiler in such a manner that the water will not be discharged directly against surfaces exposed to gases of high temperature or to direct radiation from the fire, or close to any riveted joints of the furnace sheets or of the shell. Feedwater, other than condensate returned as provided for in Par. P-308, shall not be introduced through the blow-off except for boilers having over 2500 sq ft of heating surface, where it may be used as an emergency feed connection only in addition to the regular feed connection.

When a horizontal-return tubular boiler exceeds 40 in. in diameter, the feedwater shall discharge at about three-fifths the length from that end of the boiler which is subjected to the hottest gases of the furnace (except a horizontal-return tubular boiler equipped with an auxiliary feedwater heating and circulating device), above the central rows of tubes. The feed pipe shall be carried through the head or shell furthest from the point of discharge of the feedwater in the manner specified for a surface blow-off in Par. P-307, and be securely fastened inside the shell above the tubes.

In vertical tubular boilers, feedwater shall be introduced at a point not less than one-fourth the length of the tube for tubes 4 ft and less in length above the lower tube sheet or crown sheet. For tubes more than 4 ft in length, the feedwater shall be introduced at a point not less than 12 in. above the crown sheet.

TABLE P-11. INSERT THE FOLLOWING NOTATION UNDER THIS TABLE:

The discharge capacities given in the above table may be interpolated to determine the values for intermediate pressures.

PAR. P-332. FIRST SECTION REVISED:

Each boiler shall conform in every detail to these Rules, and shall be distinctly stamped with the symbol as shown in Fig. P-25, denoting that the boiler was constructed in accordance therewith.

REVISED FIRST SENTENCE OF SECOND SECTION:

After obtaining the stamp to be used when power boilers are to be constructed to conform with this section of the A.S.M.E. Boiler Code, a state inspector, or a municipal inspector of any state or municipality that has adopted the Code, or an inspector employed regularly by an insurance company and who is qualified under the rules of such states or municipalities to inspect boilers, is to be notified than an inspection is to be made; and he shall inspect such boilers during construction and after completion.

REVISED LAST SENTENCE OF SECOND SECTION TO FORM A SEPARATE SECTION:

This data sheet, together with the stamping on the boiler, shall be a guarantee by the manufacturer that he has complied with all the requirements of this section of the Code.

SPECIFICATIONS S-2.

Revisions have been proposed in Pars. 1, 2, 3, 6, 7, 9, 10, 11, and 14 of this specification to make them correspond with revised paragraphs in identical A.S.T.M. Specifications A89-31T. For detail schedule of the revisions, communicate with the Secretary of the Boiler Code Committee.

SPECIFICATIONS S-3.

The following paragraphs have been proposed for revisions:

Insert a paragraph at the beginning of the specifications to read:

Scope. These specifications cover steel plates or sheets under $^1/_4$ in. in thickness to be used for brazing.

Par. 5. Revise to read:

Two tension tests and two bend tests shall be taken from each heat; each test from a different sheet or plate as rolled.

Par. 6. Revise to read:

6. *Marking.* The name or brand of the manufacturer and the melt number shall be legibly stenciled on each sheet or plate.

SPECIFICATIONS S-9.

Revisions have been proposed in Pars. 1, 10*a*, and 12 of these specifications to make them identical with revised paragraphs in A.S.T.M. Specifications A96-31. For detail schedule of the revisions, communicate with the Secretary of the Boiler Code Committee.

SPECIFICATIONS S-19.

A revision has been proposed in Par. 13 of these specifications to make them identical with corresponding revised paragraph in A.S.T.M. Specifications A72-31. For detail schedule of the revision, communicate with the Secretary of the Boiler Code Committee.

EXEMPTION CLAUSE PRECEDING PAR. L-1. REVISE EXEMPTION CLAUSE PRECEDING PAR. L-1 TO READ:

These rules are not intended to apply to boilers of locomotives which are subject to Federal inspection and/or control.

PAR. L-82. REVISE FIRST SENTENCE OF SECOND SECTION TO READ:

After obtaining the stamp to be used when locomotive boilers are to be constructed to conform with this section of the A.S.M.E. Boiler Code, a state inspector, or a municipal inspector of any state or municipality that has adopted the Code, or an inspector employed regularly by an insurance company and who is qualified under the rules of such states or municipalities to inspect boilers, is to be notified that an inspection is to be made; and he shall inspect such boilers during construction and after completion.

REVISE LAST SENTENCE OF SECOND SECTION TO READ:

This data sheet, together with the stamp on the boiler, shall be a guarantee by the manufacturer that he has complied with all the requirements of this section of the Code.

PAR. H-35. REVISED:

H-35. Boilers of the wet-bottom type having an external width of over 36 in. shall have not less than 12 in. between the bottom of the boiler and the floor line, with access for inspection. When the width is 36 in. or less the distance between the bottom of the boiler and the floor line shall not be less than 6 in., and when the width of the wet part of the bottom is 24 in. or less, it shall not be less than 4 in.

PARS. H-46 AND H-99. REVISE FIRST SENTENCE TO READ:

Safety valves shall be connected to the boilers independent of other connections, and be attached directly or as close as possible to the boiler without any unnecessary intervening pipe or fitting except the Y-base forming a part of the twin valve or a steam equalizing pipe between boilers.

PARS. H-55 AND H-108. REVISE THIRD SECTION TO READ:

Connections to steam-gage siphons shall be of non-ferrous metal when smaller than 1-in. pipe and longer than 5 ft between the siphon and point of connection of pipe to boiler, and also when smaller than $\frac{1}{2}$-in. pipe and shorter than 5 ft between the siphon and point of connection of pipe to boiler.

PAR. H-66. ADD THE FOLLOWING SENTENCE:

After obtaining the stamp to be used when welded heating boilers are to be constructed to conform with this section of the A.S.M.E. Boiler Code, a state inspector, or a municipal inspector of any state or municipality that has adopted the Code, or an inspector employed regularly by an insurance company and who is qualified under the rules of such states or municipalities to inspect boilers, is to be notified that an inspection is to be made; and he shall inspect such boilers during construction and after completion.

PAR. H-81. REVISE LAST SENTENCE TO READ AS FOLLOWS:

The inspector shall be a state inspector, or municipal inspector of any state or municipality that has adopted the Code, or an inspector employed regularly by an insurance company and who is qualified under the rules of such states or municipalities to inspect boilers.

PAR. M-20. ADD THE FOLLOWING SENTENCE TO THE SECOND SECTION:

After obtaining the stamp to be used when miniature boilers are to be constructed to conform with this section of the A.S.M.E. Boiler Code, a state inspector, or a municipal inspector of any state or municipality that has adopted the Code, or an inspector employed regularly by an insurance company and who is qualified under the rules of such states or municipalities to inspect boilers, is to be notified that an inspection is to be made; and he shall inspect such boilers during construction and after completion.

ADD FOLLOWING SECTION TO THIS PARAGRAPH:

This data sheet, together with the stamping on the boiler, shall be a guarantee by the manufacturer that he has complied with all the requirements of this section of the Code.

PAR. CA-5. REVISED:

CA-5. Cracks which are generally transcrystalline (across the grains) in character and may occur both internal and external to the riveted, welded, and expanded joints in any section of the boiler, are attributed to one or more of the following causes: Steel of unsuitable quality, excessive internal stresses, imperfect thermal or mechanical treatment during fabrication, unskilled or abusive treatment during repairs, or to corrosion and certain other severe operating conditions.

Cracks which are generally intercrystalline (around the grains) in character occur in boilers only in joints and seams where in certain boiler waters dissolved solids may become highly concentrated. These cracks are generally attributed to the effect of caustic soda on highly stressed metals within these parts.

This action, which is usually termed "caustic embrittlement," has taken place in cases where the boiler water contains but little sodium sulphate in proportion to the total sodium hydroxide and sodium carbonate alkalinity.

In cases of boiler failures from cracks, competent advice should be secured to determine the cause for such failures.

Operating evidence supplemented by laboratory work indicates that if not less than the following ratios of sodium sulphate to total sodium hydroxide and sodium carbonate alkalinity calculated to equivalent sodium carbonate are maintained in the boiler water, "caustic embrittlement" will be inhibited:

Working pressure of boiler, lb gage	Sodium sulphate		Total sodium hydroxide and carbonate alkalinity calculated to equivalent sodium carbonate
0 to 150[a]	1	to	1
150 to 250	2	to	1
250 and over	3	to	1

[a] For cases where this ratio should be higher, see Footnote No. 1 below.

Laboratory research work has indicated that there may be other means of inhibiting "caustic embrittlement;" however, there are insufficient operating data available at the present time to prove the value of these preventive measures.

Pending further operating data from boilers in service, it is recommended that the requirements of Par. I-44 of Section VI of the Code be extended to all riveted, welded, or expanded joints, and that careful examination of all joints be made if leaks occur and do not remain tight after proper calking.

[1] Bulletin No. 216 of the Engineering Experimental Station, University of Illinois, entitled "Embrittlement in Boilers," 1930, pp. 76–78.

A.S.M.E. Boiler Code Committee Work

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of The American Society of Mechanical Engineers for approval, after which it is issued to the inquirer and published in MECHANICAL ENGINEERING.

Below are given records of the interpretations of the Committee in Cases Nos. 688, 694, 700, 704, and 705–709 inclusive, as formulated at the meeting on January 15, 1932, all having been approved by the Council. In accordance with established practice, names of inquirers have been omitted.

CASE No. 688

Inquiry: When used in the construction of the boiler pressure parts, can material made in accordance with Specification S-2 be considered as being in compliance with Pars. P-2 and P-3 of the Code?

Reply: Revised A.S.T.M. Specification A89-31T provides for firebox-quality plate. The Boiler Code Committee recommends that, pending the adoption of revisions to Specification S-2 for Steel Plates of Flange Quality for Forge Welding to make them identical with A.S.T.M. Specification A89-31T, the use of this revised specification be permitted as being in compliance with Pars. P-2 and P-3.

CASE No. 694

Inquiry: Is it the intent of Par. P-314 of the Code, which specifies that feedwater shall not be introduced into a boiler in such a manner as to be discharged close to riveted joints of shell or furnace sheets, that this limitation shall apply to the longitudinal riveted joints in the barrels of locomotive-type boilers?

Reply: There are ordinarily no structural difficulties that would make it necessary to introduce feedwater into a boiler close to a riveted joint, and as this practice is definitely prohibited by Par. P-314, it is the opinion of the Committee that the point of feed entry should be kept removed from any riveted joint in all types of boilers.

CASE No. 700

Inquiry: Is it the intent of the requirement for the nick-break test in Par. U-69 of the Code to absolutely prohibit more than six gas pockets per square inch of any size?

Reply: It is the opinion of the Committee that the intent of the requirement for nick-break test in Par. U-69 will be met if there are more than six gas pockets per square inch, provided the total area thereof does not exceed the area of six gas pockets, each $1/16$ in. in diameter.

CASE No. 704

Inquiry: What is the maximum allowable unit joint working stress for Class 3 vessels, with double-welded lap-type longitudinal joints for thickness of $3/8$ in. or less under the provisions of Par. U-73 of the Code? It is noted that this allowable working stress is not provided for in Par. U-70.

Reply: It is the opinion of the Committee that the maximum unit joint working stress for double full-fillet lap welds for longitudinal joints should be 7000 lb. It is therefore proposed to insert the following as the third section of Par. U-70:

> For double full-fillet lap welds for longitudinal joints and for material thickness of $3/8$ in. or less, the maximum unit joint working stress ($S \times E$) shall not exceed 7000 lb per sq in.

CASE No. 705

Inquiry: Is it necessary to limit the total length of the specimen and the distance between the supports as shown in Fig. U-13 of the Code for the nick-break test?

Reply: It is the opinion of the Committee that the dimension "about 6 in." in Fig. U-13 is too restrictive and should be replaced by a reference letter *A*, with the definition that "*A* is to be about 3 in. for $1/4$-in. plate and as close together as practicable for greater thicknesses."

CASE No. 706

(In the hands of the Committee)

CASE No. 707

Inquiry: Request is made for a revision of that part of Par. P-314 of the Code which provides for location of the feed pipe in an h.r.t. boiler above the central row of tubes when the shell diameter exceeds 36 in., so that it will apply only to boilers over 40 in. in diameter.

Reply: It is the opinion of the Committee that the present requirement for the discharge of the feedwater in h.r.t. boilers in excess of 36 in. should be changed to apply to boilers in excess of 40 in. in diameter. It is therefore proposed to revise this requirement so as to make it apply to h.r.t. boilers in excess of 40 in.

CASE No. 708

Inquiry: How is the allowable working pressure for a corrugated bend in seamless pipe to be determined under the Code requirements?

Reply: In computing the allowable working pressure of a corrugated pipe, it should be figured for the original pipe from which the corrugated bend is made and the dimensions of which are the same as the end straight portions of the pipe where it is not corrugated, provided there is no thinning down in the corrugations.

CASE No. 709

Inquiry: Will it be permissible under the requirements of the Power Boiler Section of the Code to use electric-resistance-welded steel pipe or tubing which meet the requirements as to chemical and physical properties of Specifications S-18 and S-17 in the construction of Code boilers?

Reply: The Boiler Code Committee recommends that electric-resistance-welded steel pipe or tubing be accepted under the classification of lap-welded pipe (Specification S-18) and lap-welded tubes (Specification S-17) provided they meet all chemical, physical, and other requirements of lap-welded steel pipe or tubes in those specifications.

Correspondence

Invention, Unemployment, and Patent Control

TO THE EDITOR:

Mr. Bertell M. King, in his letter which appears on page 154 of the February issue of MECHANICAL ENGINEERING, brings up a point that is of more vital importance than ever before. On page 112 of the same issue there is an abstract of a lecture by H. R. Ricardo, F.R.S., in which the statement is made that the gasoline engines now in service exceed 300 million hp, or ten times that of all other power in the world. This gives us more than 330 million hp in service.

Assuming that ten men can exert, over a period of eight hours out of twenty-four, the equivalent of one horsepower, and that an engine or other power producer will average to operate during 24 hours a day with the same reliability that men can work for eight hours, we have in power-producing equipment in the world an equivalent of nearly ten billion man power. The total population of the world being given as two billion, it would require five times as many able-bodied men as the total population of the world to supply as much energy.

This growth in mechanical power has taken place almost entirely during the past 150 years. Back in 1780 water falls, wind, and a few inefficient and crude steam engines produced what mechanical power was produced. Yet, in general, the social and the economic system we have today is like that of 150 years ago in all important respects. The revolutionary methods attempted in Russia have not been carried on long enough to indicate whether or not they will prove permanently successful.

One thing, however, is obvious: inventions cannot be exploited in the future as they have in the past without disastrous results. In practice, today, the inventor, after he has patented his invention, has to fight for his rights in the courts. When he is through, the corps of lawyers he has employed have reaped the profits, and he may be worse off financially than before he invented anything. Some manufacturers become very rich through the use of the invention. Many men are thrown out of employment. This goes on until unemployment increases to such a degree that power to buy on the part of the consumers is reduced to a point where what is produced cannot be sold. There is then a business depression, and ultimately the very manufacturing concerns that made such great profits from the invention become bankrupt.

Our real problem is one of distribution and consumption. We have a producing capacity far in excess of our consuming capacity. The consuming capacity depends upon the buying power, the desire to buy, and the ability to consume. Consuming ability requires both buying power and leisure time that can be devoted to consuming.

Sight must not be lost of the fact that each invention increases production and reduces the labor required in production. This demands more consumption. As production is increased the consuming time of all consumers must also be increased and their power to buy increased in the ratio required to take care of production. Striking and maintaining the proper balance is an engineering research problem, but applying and enforcing the findings requires that some department in the Federal Government be given full powers and authority to enforce them.

J. E. BULLARD.[1]

Providence, R. I.

TO THE EDITOR:

Referring to Mr. Bertell W. King's letter in the February issue, with which I heartily agree, we have to deal with two distinct classes of inventions: (1) Those which produce a genuinely new consumption; and (2) those which only constitute improvements of known products, or of processes for their manufacture.

The first class is beneficial in so far as it opens new fields for human toil. Whether wholly a benefit to the toilers or only partly so depends upon the course of action taken by the inventor in exploiting his invention. The second class mostly lacks beneficial effect from the toiler's viewpoint, because actually it causes the eggs to be transferred from one basket to another and does not add to their number.

For instance, an improvement in a process of manufacturing which results in an elimination of a certain number of hours of human toil means an actual loss to the asset sheet of hours of toil, and consequently to mankind, looked at from a humanitarian viewpoint, no matter what the gain may be to those who own the basket into which the eggs were transferred. I believe that it is this kind of invention which should be watched. It is this process of transferring eggs from one basket into another with no advantage to the first basket which has brought about the present serious condition of affairs, and which, in my humble opinion, is not merely the "swing of the pendulum" but is the outcome of the cold fact that too many baskets have been emptied of eggs.

Is it not time that at least this "technical" egg transfer be studied more seriously by the engineering profession, which, I believe, is to some extent, perhaps *nolens volens*, an accessory to this transaction?

ARNOLD PFAU.[2]

Milwaukee, Wis.

TO THE EDITOR:

In his letter in the February issue, Mr. Bertell W. King proposes to tax the use of inventions. It is hard for me to see how this plan will prevent unemployment and at the same time compensate the inventor.

We may forecast the results if Mr. King's plan is adopted. No manufacturer wishes his competitors to obtain the use of his own bright ideas. That is why he has them patented. On the other hand, he will ape his rivals' progress wherever possible. Now if a labor-eliminating device were offered to industry by the Government for the payment of a reasonable fee, it is only natural to suppose that all manufacturers would wish to buy the use of this device in order to deprive their competitors of its exclusive use. All factories to which this device would apply would then eliminate the unnecessary workers and use the wages saved to pay for the license fee. This would be a great help to the inventor, but I can't see where it would help the unemployed. Where now a labor-eliminating machine is controlled by only a small number of factories, under Mr. King's plan it would be possible for a large group of plants to use it.

Furthermore, many ideas for increasing efficiency originate in the brains of factory engineers employed for that purpose. They are patented to prevent competitors from using them.

[1] Distribution Engineer. Assoc-Mem. A.S.M.E.
[2] Consulting Engineer, Allis-Chalmers Mfg. Co. Mem. A.S.M.E.

If the Government charged a fee for the use of patents, these factories would save the cost of the fee but would use their unpatented ideas anyway. The result would be the same if they had them patented: their rivals would also put them to use. So why have them patented?

I contend that all the members of an industry would license an invention that would be useful to them. Then what is to prevent them from passing the cost of the license fee along to the public in the form of an increased selling price? How will this reduce the burden of taxation? If new labor-eliminating devices are open to all industry for the payment of a "reasonable" fee, how will additional unemployment be prevented thereby?

The way to stop machinery from displacing men is to stop inventing such machinery. There is a wide difference between labor-saving machinery and labor-eliminating machinery. Any device that saves men from toil should be welcomed. But any machine that deprives men of the right to work is a curse. Unemployment will not be solved by licensing labor-eliminating machines to manufacturers. Once upon a time such devices were signs of progress. Now they are retrogressive. Let inventors in general stop devising new schemes to decrease payrolls. Let them concentrate their energies on getting industry out of the present chaos. Enough ingenuity is needed in managing the present state of affairs to satisfy the creative cravings of all the successors to Edison.

W. C. SAYLOR.[3]

Baltimore, Md.

Up-Flow vs. Level-Flow Die-Casting Machines

TO THE EDITOR:

The letter from Mr. Ernst Seidewitz published in the January, 1932, issue of MECHANICAL ENGINEERING on the subject of "Up-Flow vs. Level-Flow Die Casting Machines" is interesting.

Mr. Seidewitz apparently refers to a machine with a vertical parting plane as being a level-flow machine, and a machine with a horizontal parting plane as being an up-flow machine. A machine in which the die parting plane is vertical is a machine in which the die when it opens and closes moves in a horizontal direction. One half of the die may be held stationary and the other half moved to and from this stationary half, movement being in the horizontal. This can be and is accomplished in many different types of machines irrespective of whether the metal enters on the horizontal or on the vertical. With a vertical parting plane, we can introduce the metal along the parting line either from the bottom, in which case we have an up-flow machine, from the side, in which case we have a level-flow machine, or from the top, in which case we have a down-flow machine, but in all of these cases we have a split-gate machine. We still have another alternative, and that is to introduce the metal *through* one half of the die, in which case we have a level-flow machine and at the same time a center-gate machine. If we have the die mounted so that its parting plane is horizontal with one half of the die stationary, the other half then moves vertically. The upper die may be the stationary one and the bottom die be caused to move up and down, or the bottom die may be the stationary one and the upper half of the die caused to move up and down to meet it. In this case we can introduce the metal along the parting plane or through one half of the die. If we introduce the metal along the parting plane, we again have a level-flow split-gate type of machine; if through one half of the die, we have a vertical-flow center-gate type of machine. The important consideration is not whether the metal flows up or sidewise, but whether the metal flows along the parting plane or through one half of the die and whether the parting plane is horizontal or vertical.

Mr. Seidewitz is of course dealing only with very small dies, as indicated by his statement that the moving portion of the die will weigh from 50 to 150 lb and that the stationary portion may sometimes weigh around 200 lb. In the writer's experience a die weighing only 200 or 300 lb in all is considered as an average or even a small one, and dies are used regularly in every-day production weighing 1000 to 2000 lb, and often dies weighing 4000 to 8000 lb total are constructed.

Nor can one agree with Mr. Seidewitz that experience has taught that the mounting and dismounting of dies is a difficult and dreaded piece of work. Properly designed dies need not be mounted and dismounted as frequently as would be inferred from Mr. Seidewitz' letter. Many dies require hours to mount, whereas others can be mounted in a few minutes. If the casting being produced is one in which small cores are being broken frequently, then something is wrong with the design of the die or the design of the casting being produced, and such errors should be corrected. There is no economy in attempting to cast holes so small in diameter or so deep into the casting as to cause excessive breaking off of the cores. In many cases it is sufficient to simply spot the place for the hole and to drill it afterward. In others, it has been possible to build dies so that small core pins can be replaced without complete dismounting of the die.

Mr. Seidewitz states that a short travel of the nozzle of the gooseneck from its starting point to the gate bushing is conducive to a quicker alignment and to a casting of higher grade. These conclusions of his are not supported by fact or practice in the industry. It is difficult to see how the travel of the nozzle itself can be translated into terms of the grade of casting produced. It might be said that the shorter distance through which the molten metal must travel after the nozzle is in position is conducive to the production of better castings, although this statement would also be somewhat questionable.

Considering the vertical versus the horizontal parting plane, we must bear in mind the question of hazard to the workmen. When molten metal is forced under pressure into a die, there is a possibility that the metal will squirt out of the die anywhere along the parting lines of the die. If the parting plane of the die is horizontal, then the metal is liable to squirt in all directions, and it is unsafe to have the operator stand where he can see the die while the casting is being made. If the parting plane is vertical, however, the metal can squirt only in a vertical plane, and the operator can stand at either side of this plane of danger, and can watch the die while the casting is being made and see what is going on. This is a very important feature favorable to machines using dies with parting planes vertical as against those using dies with parting planes horizontal.

The characterization of die-casting machines as machines requiring frequent repairs and replacements and frequently suffering general breakdown as compared with metal-working machines in general, is an unfair one. A survey of the die-casting industry as made recently by the writer and covering over 80 per cent of the productive capacity in this country, showed that a majority of the leaders today are building die-casting machines on sound engineering principles and designed so that the machines do not suffer such frequent breakdowns as Mr. Seidewitz would seem to indicate.

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BOOK REVIEWS AND LIBRARY NOTES

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Mechanics of Plastic Bodies

PLASTICITY: A Mechanics of the Plastic State of Matter. By A. Nádai, assisted by A. M. Wahl. Engineering Societies Monograph published by the McGraw-Hill Book Co., Inc., New York, 1931. Cloth, 6 × 9 in., xxix + 349 pp. $5.

REVIEWED BY EUGENE C. BINGHAM[1]

IN 1927 Dr. Nádai published under the imprint of Julius Springer, Berlin, his work "Der bildsame Zustand des Werkstoffe," but this valuable work has until now remained inaccessible to those not familiar with the German language. Now the four national engineering societies, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers, and the American Society of Electrical Engineers, have made arrangements with the McGraw-Hill Book Co., Inc., to publish a series of selected books of usefulness to engineers or to industry, the series to be known as the Engineering Societies Monographs. The societies are, with the publishers, to be commended for this undertaking, which will no doubt render a great service in the advancement of both engineering and industry, particularly in the English-speaking world. It is worthy of note that this work on plasticity should have been chosen for the first monograph of the series. Monographs on highly specialized topics are not apt to be profitable, but the object of the societies is not profit primarily but rather to make accessible valuable information which otherwise would be delayed in publication.

Dr. Nádai's original work was a slender volume of 179 pages, while the present volume comprises twice that number. The greater part of the expansion consists of new material—for example, Part II, which deals with applications of the mechanics of the plastic state to problems of geology and geophysics. An index has also been added, and the number of figures has been increased from 298 to 397. The index, however, is far from being complete. The translation has been well done and typographical errors are remarkably few. On p. 20, "similar" should read "similarly," and on p. 53, ϵ_{zx} should read ϵ_{zzx}.

The author does not define plasticity except in very general terms nor does he describe how, if at all, it can be measured quantitatively; he does not even make it clear whether he regards plasticity as a simple fundamental property or a complex property. On the other hand, he is by no means lacking in clarity when dealing with hardness, for he frankly admits the difficulty of defining or quantitatively measuring it. He says (p. 235): "Hence hardness cannot be considered as simple a mechanical property as elasticity or plasticity." This would lead one to suppose that plasticity is to be considered a simple property. Since the author discusses the nature of viscous flow on pp. 4, 5, and 282–284, in connection with the nature of plasticity, one is left with the impression that plasticity is a sort of viscosity applied to solids. However, the insufficiency of this conception is admitted on p. 5, where it is stated that "the above-mentioned properties of fluids and solid bodies do not suffice to classify materials with regard to their mechanical behavior, as a few examples will indicate." He then goes on to describe pitch-like materials which, in the opinion of the author of this review, are apparently devoid of yield value, but nowhere does he recognize the possibility of the two properties *yield value* and *mobility* making up the complex property of plasticity. On p. 282 the author states that he has always reserved the term viscosity, as he should, for those cases of flow which follow the Newtonian law, viz., that the shearing stress is directly proportional to the rate of flow. The mechanism suggested on p. 283 to explain the viscosity of liquids is unfortunately wrong. The explanation given is the true mechanism of the viscosity of *gases*, but it has long been known that the viscosity of liquids requires a further explanation because the viscosity of liquids, unlike that of gases, decreases as the temperature is raised. Not having a perfectly clear-cut distinction between viscosity, elasticity, and plasticity, it is not surprising that when treating of soft materials such as paraffin, no attempt is made to get a quantitative measure of the plasticity; and no mention is made of those investigators who have attempted to measure the internal friction of metals in a quantitative manner. Some of these attempts were poorly conceived perhaps, but a critical discussion of them would be of the greatest value. The reviewer refers to the work of Lord Kelvin, Guye, and a number of co-workers. Others such as Kurnakov have forced the softer metals through orifices under conditions which would seem to lead to a quantitative measure of the plasticity constants. The work of Joffé promised to lead to quantitative laws of flow for the crystalline state. It is a disappointment to find no discussion of this interesting work. The important researches of Beilby on the flow of solids and of Bouasse on elasticity are not referred to. The work of Day and his associates in making marble and other brittle solids flow deserves mention, as well as the highly refined measurements upon the flow of ice and similar bodies, such as those of Deeley and Parr.[2]

Dr. Nádai has taken a point of view readily understandable

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[2] References may be found to the authors noted in the Rheology Index, *Journal of Rheology*, vol. 2 (1931).

to mechanical engineers, who presumably constitute the greater part of the audience he was addressing, and it is highly praiseworthy for an author to make himself understandable to his audience. There is, however, no objection and in fact there is every reason in making it clear that the problems of flow are not exclusively problems of conventional mechanics. The problems of flow may therefore be approached from a somewhat different point of view. That this divergence of viewpoint may be detrimental, is well expressed by Dr. Guy Barr of the National Physical Laboratory, in a letter received while this review was being written. He says, "I find that I am often at cross purposes when I discuss 'viscosity' of metals with our metallurgists. It seems to me that there is a gap in our knowledge which may perhaps be filled in after a study of some such materials as coal-tar pitch which behave as solids under impact and as liquids under small rates of shear." Dr. Nádai is sympathetic with both points of view, and it is to be hoped that in a later revision he will bring about an amalgamation. In fact, he arranged for a symposium upon the flow of metals at the meeting of the Society of Rheology at Rochester in December last.

The book shows many excellent photographs of strain figures on different materials as well as photoelastic effects and etch figures, which give the reader valuable information as to the distribution of stresses under tension, compression, or torsion. Mohr's representation of stresses is given. Several experimental methods are described which are of value. Dr. Nádai discusses the commonly expressed statement that glass tubing supported at the ends will be permanently deformed by its own weight, and finds it largely incorrect.

There is very rapidly coming a demand for the greatest possible strength under high load and at elevated temperature, and with the least possible excess of material. It is therefore safe to predict that the new material supplied by this treatise will be very highly appreciated. It is only to be hoped that Rheology will add a fresh point of view which will before long greatly contribute to our knowledge of materials, by giving more exact definitions and properties which can be exactly measured. Too much is at stake to be without them, if they are at hand.

It is of more than ordinary interest that while this review was being prepared a volume appeared in Great Britain which is also an English translation of a German treatise on the same general subject of plasticity. The writer refers to "The Physics of Solids and Fluids," by Ewald, Pöschl, and Prandtl, translated by Dougall and Deans. The articles used originally appeared in the eleventh edition of Müller Pouillet's Lehrbuch der Physik," but they have been amended and supplemented. Since Dr. Nádai was associated with Dr. Prandtl for eight years, there is a considerable resemblance between these two books in their subject-matter. The latter half of the English book is given over to the flow of liquids and gases, whereas Part II of the American book deals with geophysics. The American book is addressed primarily to engineers, while the English book is addressed to physicists, and each forms a useful supplement to the other.

Books Received in the Library

HÜTTE, DES INGENIEURS TASCHENBUCH. Edited by Akademischer Verein Hütte. Vol. 2. 26th edition. W. Ernst & Sohn, Berlin, 1931. Cloth, 5 × 8 in., 1196 pp., illus., diagrams, charts, tables, 17.50 r.m.

"Hütte" has been a guide to engineers for seventy-five years, during which period it has arrived at a degree of excellence unsurpassed by any other handbook of engineering data. The present volume, devoted to mechanical and electrical engineering, shows little change in form from that of its predecessor. Revisions and extensions of the text and tables have been made wherever necessary though, and the material has been rearranged in certain sections. Type changes have been made to facilitate quick reference.

INCREDIBLE CARNEGIE, the Life of Andrew Carnegie (1835–1919). By J. K. Winkler. Vanguard Press, New York, 1931. Cloth, 6 × 9 in., 307 pp., illus., $3.50.

Carnegie's spectacular rise from poverty to great wealth is told in interesting, journalistic fashion in this biography. The author is especially interested in the complex character of the man and the methods by which he achieved success.

PHYSICS OF HIGH PRESSURE. By P. W. Bridgman. Macmillan Co., New York, 1931. Cloth, 398 pp., illus., diagrams, charts, tables, $5.50.

Dr. Bridgman's book, while primarily a summary of work in which he has been engaged in the last twenty-five years, also aims to be a fairly complete survey of all important work in the field of high pressure. A chapter of historical introduction is followed by descriptions of the general technique of high-pressure work and of methods of measuring pressure. Succeeding chapters discuss the compressibility of solids and the effect of pressure upon the melting, electrical resistance, thermoelectric properties, conductivity, and viscosity of materials. Many references are included. The book is a welcome addition to the few in this field.

QUEEN OF THE SCIENCES. By E. T. Bell. Williams & Wilkins Co. and Associates in Cooperation with the Century of Progress Exposition, Baltimore, 1931. Cloth, 5 × 8 in., 138 pp., diagrams, $1.

A rapid history of mathematics, intended for the intelligent layman who wishes to know what mathematics is, what its object is, and what mathematicians are accomplishing. Dr. Bell is remarkably successful in presenting the philosophy, aims and methods of mathematics, and showing its importance in intellectual and scientific advance.

STAINLESS IRON AND STEEL. By J. H. G. Monypenny. Second edition. John Wiley & Sons, New York, 1931. Cloth, 6 × 10 in., 575 pp., illus., diagrams, charts, tables, $7.

A good picture of the present state of the art of making and using stainless steels is offered in this work, the most comprehensive available in the English language. The author has endeavored to present recent developments in shape for use by manufacturer and user, and especially to assist the latter in selecting the best material for a given purpose. The composition of these steels, the effects of varying treatment and composition on their properties, their resistance to corroding media, their manufacture, working, and properties, and the selection of steels for various purposes are discussed. A chapter is devoted to heat-resistant steels.

UM DIE ZUKUNFT DER TECHNISCHEN FACHPRESSE. By K. Schulz. VDI-Verlag, Berlin, 1931. Paper, 6 × 9 in., 154 pp., 5 r.m.

The subject of this work is the reorganization of the technical press, especially that of Germany. Dr. Schulz describes its evolution from the seventeenth century beginnings to the World War, and discusses the problems that it has faced since that catastrophe. He discusses the frequently opposed interests of the author and reader, and advertiser and publisher, and suggests ways toward better stabilization of the means of disseminating technical information.

CURRENT MECHANICAL ENGINEERING LITERATURE

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Air Compressors

LUBRICATION. Le graissage des compresseurs d'air incidents et accidents dans les installations d'air comprime, P. Martinet. Technique Moderne v 24 n 1 Jan 1 1932 p 1–5. Lubrication of air compressors discussed under heads: formation of combustible mixtures through lubrication; hazardous temperature rise; causes of ignition; auto-ignition; ignition in pipelines and tanks.

AIRPLANES

METAL CONSTRUCTION. Problemi structturals nella costruzione degli aeroplani giganti, E. T. della Floresta. Aerotecnica v 11 n 8 Aug 1931 p 971–91. Structural problems in manufacture of giant airplanes; relative merits of different materials, particularly alloy steels and duralumin; review of representative types of joints.

PERFORMANCE CALCULATION. Ueber Flugleistungsstatistik, H. B. Helmbold. Zeit fuer Flugtechnik und Motorluftschiffahrt v 22 n 21 Nov 14 1931 p 629–39. Comparison of design factors controlling performance for different types of airplanes; rating coefficients for climbing speed, ceiling, etc.

Ueber das Zusammenwirken von Flugwerk und Triebwerk, M. Schrenk. Zeit fuer Flugtechnik und Motorluftschiffahrt v 22 n 23 and 24 Dec 14 1931 p 695–702 and Dec 28 p 721–7. Performance calculation with particular regard to interaction of propeller and fuselage or wings; efficiency under different conditions of flight, especially at high altitudes.

PROPELLERS. Esperimenti su Eliche per Tutti gli Stadii di Funzionamento, A. Faraboschi. Aerotecnica v 11 n 4 Apr 1931 p 395–410. Experiments on propellers at various speeds and for different values of pitch-diameter ratio; theoretical and experimental investigation at Aeronautical Laboratory of Institute of Technology at Turin.

Esperienzec on Eliche Intupate, L. Stipa. Aerotecnica v 11 n 8 Aug 1931 p 923–53. Experiments on improvements of planes by providing propeller with cowling arrangement, or having it work in connection with venturi-shaped fuselage.

TORSIONAL STIFFNESS. Die Verdrehsteifigkeit und Verdrehfestigkeit von Flugzeugbauteilen, H. Hertel. Luftfahrtforschung v 9 n 1 Aug 1 1931 p 1–56. Torsional stiffness and strength of structural components of airplanes, including wood and metal; measuring methods and equipment; investigation of box section and thin-walled tubes.

WINGS—DESIGN. Zur genauen Berechnung vielholmig-parallelstegiger, ganz und halbfreitragender mittelbar und unmittelbar belasteter Fluegelgerippe, E. Saenger. Zeit fuer Flugtechnik und Motorluftschiffahrt v 22 n 20 Oct 28 1931 p 597–603. Accurate calculation of multispar, full, and semi-cantilever, directly or indirectly loaded wing structures; numerical examples.

AIRSHIPS

RIGID—STRESSES IN. Contribution to Analysis of Primary Stresses in Hull of Rigid Airship, L. Chitty and R. V. Southwell. Royal Aeronautical Soc—J v 35 n 252 Dec 1931 p 1103–36. Effects of forces applied at joints of tubular framework, and acting in directions parallel to longitudinals; assumed that transverse rings, or bulkheads, are completely rigid against forces tending to distort them in their own planes.

Elastizitaetstheorie des starren Luftschiffs, H. Mueller. Luftfahrtforschung v 9 n 2 Aug 25 1931 p 57–84. Elastic theory of rigid airship with particular regard to determination of loads acting in longitudinal center plane; determination of stresses in circumferential members of frame sections.

ALLOYS

HEAT-RESISTING. Thermal Expansion of Heat-Resisting Alloys: Nickel-Chromium, Iron-Chromium, and Nickel-Chromium-Iron Alloys, P. Hidnert. U S Bur Standards—J Research v 7 n 6 Dec 1931 p 1031–66 12 supp plates. Data on linear thermal expansion of various heat-resisting alloys; effects of chromium content, carbon content, heat treatment, etc. on coefficients of expansion of iron-chromium alloys for various temperature ranges; comparison of coefficients of expansion of three groups of alloys.

ALUMINUM

SHEET—DRAWING AND PRESSING. Verfahren zur Herstellung von Aluminiumgehaeusen, F. Augst. Werkstattstechnik v 25 n 23 Dec 1 1931 p 533–5. Cold drawing and pressing methods and equipment for shells, with particular regard to design of dies.

AMMONIA COMPRESSORS

COMPOUND. Kaelte- Verbundkompressoren in der chemischen Industrie, H. Freund. Chemische Fabrik v 4 n 50, 51 and 52 Dec 16 1931 p 477–8, Dec 23 p 486–8 and Dec 30 p 494–5. Use and advantages of compound refrigerating compressors in chemical industry; examples of design and operation.

AMMONIA CONDENSERS

HEAT TRANSMISSION IN. Value of Clean Condenser Surfaces, M. F. Knoy. Power v 75 n 4 Jan 26 1932 p 135. Effects of fouled condenser surfaces; curve showing variation of horsepower with condenser pressure.

ASH HANDLING

BOILER-HOUSE EQUIPMENT. Enlévement des cendres, scories et machefers dans les chaufferies, J. Lacasse. Technique Moderne v 24 n 1 Jan 1 1932 p 10–3. Handling of ash, cinders, slag, and soot in boiler houses; soot blowers in Cail-Steinmuller boiler; dust-removal equipment; complete ash-handling equipment illustrated in cross-section.

AUTOMOBILES

PERFORMANCE CALCULATION. Massnahmen zur Steigerung der Reisegeschwindigkeit von Kraftfahrzeugen, W. Kamm, W. Seyerle and H. G. Snay. VDI Zeit v 75 n 50 Dec 12 1931 p 1503–7. Measures for increasing traveling speed of motor vehicles; calculation of performance, particularly acceleration on basis of rolling and air resistance and operating characteristics of engine; gear ratios and flexibility.

OSCILLATIONS—ANALYSIS. Ausgleichvorgaenge bei Automobilfedern, R. Slaby. Automobiltechnische Zeit v 34 n 34–5 Dec 15 1931 p 775–80. Mathematical analysis of oscillations with particular regard to superimposition of oscillations due to tire and spring characteristics.

SELECTIVE GEAR CHANGING. Vacuum-Operated Selective Rear Axle Gear Ratio on New Auburn 8's and 12's, A. F. Denham. Automotive Industries v 66 n 2 Jan 9 1932 p 42–5 and 76. New features of 1932 models with particular regard to 12-cylinder V-engine having 45-deg angle between cylinder banks and single central camshaft; pre-selective gear changing.

AUTOMOTIVE FUELS

SYNTHETIC. Leuna-Benzin und katalytische Druckhydrierung, M. Pier. Chemiker-Ztg v 56 n 1 Jan 2 1932 p 2–3. Development of catalytic pressure hydrogenation at Leuna works of I. G. Dye Trust; properties and advantages of Leuna gasoline.

Bearings

BALL—MOUNTING. Queiques considérations sur le montage des roulements à billes et à rouleaux. Science et Industrie v 15 n 215 Dec 1931 p 581–4. Considerations on mounting of ball and roller bearings with particular regard to angular and radial play.

LUBRICATION. Auswertungsmoeglichkeit der Schmierungs- und Lagertheorien in der Praxis, F. Gutke. Maschinenbau v 10 n 21 Nov 5 1931 p 657–63. Possibility for valuation of lubrication and bearing theories in practice; necessary factors of influence listed according to their use in design; rules and laws of interrelation between operation, condition, and shape; importance of lubrication, oil adhesive capacity and bearing materials under various conditions of lubrication, etc.

ROLLER—FRICTION OF. Friction of Some Babbitt, Roller, and Ball Bearings, E. R. Maurer and L. E. A. Kelso. Univ Wis—Eng Experiment Station—Bul n 72 1931 48 p. Tests to determine friction of some commercial lineshaft bearings under circumstances to warrant some fair comparisons of their frictional resistances; coefficient of friction-temperature curves for various speeds and loads per bearing.

BLAST FURNACES

BLOWERS. Blast Furnace Blowing Engines, F. Johnstone-Taylor. Iron and Steel Industry v 5 n 3 Dec 1931 p 109–14. Relative merits of gas engine and turbo-blower; B.T.H. blast-furnace blower; Rateau turbo-blower, 50,000 cu ft per min capacity; Galloway gas-blowing engine, capacity 35,000 cu ft air per min; Ehrhardt and Sehmer twin gas-driven blower.

BOILER FEEDWATER

DEGASIFICATION. Kann die Wassersteinbildung durch Sauerstoffentfernung verhindert werden? K. Hofer. Gesundheits-Ingenieur v 54 n 50 Dec 12 1931 p 740–43 3 figs. Discussion of possibility of preventing boiler-scale formation by removal of oxygen from feedwater; physical and colloidal chemistry of feedwater practice; effect of salt ions and of organic substances on colloidal processes occurring in use of feedwater. Bibliography.

BOILERS

COMBUSTION CONTROL, AUTOMATIC. Automatic Combustion Control for Boilers, S. J. Clifton. Jr Instn Engrs—J and Rec Trans v 42 pt 3 Dec 1931 p 127–68 1 supp plate. Outline of functions of automatic control system; characteristics of various systems with applications.

FIRING WITH BLAST-FURNACE GAS. Corner Firing of Blast Furnace Gas, O. deLorenzi. Combustion v 3 n 7 Jan 1932 p 11–6. Excellent overall results are being obtained with blast-furnace gas in modern steam-generating units designed for corner firing; developments in use of this fuel for steam-generating purposes and characteristics of several units which typify progress of past few years; test data show advantages of corner firing as employed in steam-generating units of most modern design.

DESIGN. New Trends in Boiler Practice Indicated in 1931. Power v 75 n 1 Jan 5 1932 p 14–6. No increase in size of boilers in 1931: number of single-pass boilers were installed both here and abroad; 1800-lb-pressure unit went in operation; critical-pressure boilers built.

BROACHING

RECTANGULAR HOLES. Broaching Rectangular Holes, W. C. Betz. Am Mach v 76 n 2 Jan 14 1932 p 56–7. Problems of producing rectangular slots with smooth walls in bronze and low-carbon steel of thicknesses from 1/4 to 3/4 in.; design and operation of different types of broaches; recommended dimensions.

CAR WHEELS

FRICTION. Die Reibungszahl der quergleitenden Bewegung rollender Raeder von Eisenbahnfahrzeugen. Organ fuer die Fortschritte des Eisenbahnwesens v 86 n 19 Oct 1 1931 p 391–410. Friction coefficient for transverse sliding motion of wheels of railroad rolling stock; theoretical aspects; interpretation of full-size and model tests on different types of rolling stock and wheels of Dutch and German state railroads; rolling phenomena in curves.

CARS

ALL-METAL—FRANCE. Les nouvelles voitures metalliques pour grandes lignes étudiées par l'Office Central d'Études de Matériel de Chemins de Fer, M. P. Pla. Revue Générale des Chemins de Fer v 50 n 6 Dec 1931 p 385–403. Structural details and equipment of new metallic cars for main lines, developed by Central Office of Rolling Stock Studies of France; new cars are about 22 by 3.5 m; construction is of light weight and lends itself to standardization.

CASTINGS

FLUIDITY OF METAL. Practical Method for Studying Running Quality of Metal Cast in Foundry Molds, C. M. Saeger, Jr. and A. I. Krynitsky. Am Foundrymen's Assn—Trans and Bul v 11 n 12 Dec 1931 p 513–32 and (discussion) 532–40, 12 figs. Tests conducted for aluminum, brass and cast iron; metals cast in dry-sand molds ran further than those in green-sand molds; with increase in pouring temperature, length of test specimens increased in direct proportion to pouring temperature.

CHROMIUM STEEL

PROPERTIES. Beobachtungen beim Schmieden und Walzen von ledeburitischen Chromstaehlen, W. Zieler. Stahl und Eisen v 52 n 2 Jan 14 1932 p 38–42. Observations in forging and rolling of ledeburitic chromium steels; cracks occurring during working are attributed to coarse and irregular ledeburitic lattice work; influence of heat treatment on structure; melting point of ledeburite eutectoid.

COAL

CARBONIZATION—GREAT BRITAIN. Present Position and Future Prospects of Low Temperature Carbonisation in Great Britain, P. C. Pope. Gas World v 96 n 2475 Jan 9 1932 p 34–7. Historical outline; capacity of low-temperature plants in Great Britain totals 3000 tons coal per day; 3 main types of design; yield and value of gas; government research; hydrogenation; oil and tar; cost of smokeless fuels.

CARBONIZATION—METHODS. Methods and Apparatus Used in Determining Gas, Coke, and By-Product Making Properties of American Coals, With Results on Taggart-Bed Coal From Roda, Wise County, Va., A. C. Fieldner, J. D. Davis, R. Thiessen, E. B. Kester and W. A. Selvig. U S Bur Mines—Bul n 344 1931 p 107. Sampling and preparation; analysis; action of solvents and reagents; physical tests; assay distillation tests; microscopic examination; carbonization tests with cylindrical retorts; determination of yields; examination of products.

CONVEYORS

BELT. Proper Belt Conveyor Tension Determination, H. C. Medley. Power Plant Eng v 36 n 3 Feb 1 1932 p 115–6. Complete failure of belt conveyor installation or greatly reduced life may result from provision of improper counterweight; values of sag permissible; mathematical expression for sag.

CONTROL. Automatic Controls for Conveyors. Mech Handling v 18 n 12 Dec 1931 p 383–5. Advantage of automatic controls for manipulating conveyors of all kinds has led to perfecting of various types of such apparatus; design and operating characteristics of specific control equipment.

MONORAIL. Pedal-Operated Runway Trolley. Engineering v 133 n 3442 Jan 1 1932 p 23. Appliance, termed King aero cycle, manufactured by George W. King, Ltd., is capable, of lifting load of 1 ton and transporting it at speed of 6 mph, latter operation being effected by pedal drive similar to that employed on ordinary safety bicycle.

OVERHEAD CHAIN SYSTEM. Material Handling in Mass Production, H. C. Rundle. Indus Transmission and Conveying v 39 n 6 Dec 1931 p 5–6 and 15–6. Installation of overhead chain conveyor system for handling refrigerator parts in refrigerator department of General Electric Co.; operating advantages of system; outline of conveyor path through different buildings.

PNEUMATIC. Design and Installation of Piping for High Vacuum Pneumatic Conveyor Systems, E. H. deConingh. Heat Piping and Air Conditioning v 4 n 1 Jan 1932 p 17–20. In many industrial plants, particularly in chemical industry, unloading and conveying of materials is accomplished economically by means of pneumatic conveying pipe lines; piping installation considering design characteristics of bends for resisting wear, fittings and branches.

SYSTEMS. Conveyor Systems That Reduce Production Costs. Mech Handling v 18 n 12 Dec 1931 p 403–4. Review of various conveyor systems that reduce operating costs by reduction of manual effort; cost comparison.

CRANES

CARGO. Port Developments on River Tyne. Engineering v 133 n 3443 Jan 8 1932 p 35–6. Recent improvements of north pier at Tynemouth; third row of apron blocks has been added. Titan crane being used for purpose, designed to handle loads of 40 tons at 80 ft radius at hoisting speed of 40 fpm; radius of action can be varied from 61 to 14 ft 6 in.; at Northumberland Dock new staith, comprising two shipping berths for shipment of coal is being installed.

CUTTING TOOLS

DIAMOND. Neue Drehbaenke fuer Bearbeitung mittels Diamanten, P. Grodzinski. Maschinenbau v 10 n 24 Dec 17 1931 p 740–2. High accuracy and smooth surfaces are obtained in use of diamond tools in lathes for cutting; performance of diamond cutters described and suitable tools discussed.

TUNGSTEN CARBIDE. How to Make Carbide Tools Pay, J. M. Highducheck. Am Mach v 76 n 1 Jan 7 1932 p 16–9. Factors to be considered in determining proper and economical use of tungsten carbide; practice of Westinghouse Electric and Manufacturing Co.

CYLINDERS

STRESSES. Buckling of Cylindrical Shell Under Torsion, K. Sezawa and K. Kubo. Tokyo Imperial Univ—Aeronautical Research Inst—Report v 6 n 76 Dec 1931 p 251–314. Mathematical and experimental investigation of problem of buckling of cylindrical shell that is clamped or supported at its two ends and subjected to uniform shearing force. (In English.)

DIES

FORGING—CAST-IRON. Nickel-Chromium Cast Iron Dies, H. Chase. Am Mach v 76 n 1 Jan 7 1932 p 11–4. Addition of nickel and chromium to cast iron gives alloy that can be cast to shape for forming and forging dies; analyses of alloys used for various purposes.

DIESEL ENGINES

AUTOMOTIVE. High-Speed Diesels for Automotive Power, O. F. Allen. Power v 75 n 5 Feb 2 1932 p 165–7. Brief historical review of application of high speed Diesel engines in motor-vehicle transportation; design and specifications of specific Diesel engines.

Lanova Diesel Engine Has Ordered Air-Flow. Automotive Industries v 66 n 4 Jan 23 1932 p 126–7. Design and operating principles of experimental engine with heart-shaped combustion chamber and air storage chamber communicating with combustion chamber for control of turbulence; compression ratio 12 to 1; compression pressure 440 lb per sq in.; maximum combustion pressure 630 lb per sq in.; piston speed of 1470 ft per min; injection pressures 1150 to 1400 lb per sq in.

Leyland Road Vehicle Diesel Engine. Gas and Oil Power v 27 n 316 Jan 1932 p 13–5. Design and constructional details of overhead camshaft unit of 90 bhp at 2000 rpm introduced by Leyland Motors, Ltd.; new engine interchangeable with equivalent gasoline unit; unique form of open combustion chamber adopted; section through new Leyland vehicle-type heavy-oil engine, which develops 15 bhp per cylinder at 2000 rpm.

COMBUSTION. Combustion in High-Speed Compression-Ignition Engine, A. M. Rothrock. Nat Advisory Committee Aeronautics—Report n 401 1931 p 17. Indicator cards of Farnboro indicator analyzed according to tangent method by Schweitzer; in quiescent combustion chamber increasing time lag of auto-ignition increases efficiency and rate of combustion; by increasing air temperature during injection, start of combustion can be forced to take place during injection and so prevent detonation.

COOLING. Cooling Systems and Methods for Diesel Engines, J. M. Bloomfield. Power House (Eng) v 25 n 11 Nov 1931 p 57–60. Following factors are discussed concerning cooling of Diesel engines: hard water, open and closed systems, water-cooled exhaust manifold, cooling of water, mechanical coolers, rate of cooling, circulation of air.

DESIGN. R. N. High-Speed Heavy-Oil Engine. Gas and Oil Power v 27 n 316 Jan 1932 p 15–6. British cold-starting engine with interesting combustion chamber design and other features, including quiet running; design and constructional details; transverse and longitudinal sections of R. N. single cylinder high-speed Diesel engine.

Some Recent Developments in Diesel Engines for Electric Power Generation, E. R. Walter. Inst. Fuel—Advance Paper for mtg Dec 8 1930 p 12. General review of recent design developments; injection and combustion; duty and mean effective pressure; supercharging; principal uses and costs; retrospect and present situation; exhaust heat recovery.

FUEL INJECTION. Airless Injection Diesel Engine. Ice and Cold Storage v 34 n 404 Nov 1931 p 270–1. Design, construction and operating characteristics of latest type of Diesel engine manufactured by W. H. Allen, Sons and Co., Bedford, England, for driving refrigerating compressors for land and marine work.

Effect of Orifice Length-Diameter Ratio on Fuel Sprays for Compression-Ignition Engines, A. G. Gelalles. Nat Advisory Committee Aeronautics—Report n 402 1931 p 14. Length-diameter ratios tested ranged from 0.5 to 10; orifice diameters from 0.008 to 0.040 in.; and injection pressures from 2000 to 8000 lb per sq in.; density of air varied from 0.38 to 1.35 lb per cu ft; spray-tip penetration maximum between ratios of 4 and 6.

Jerk Pump Injection System for Compression-Ignition Engines, S. W. Nixon. Automobile Engr v 22 n 289 Jan 1932 p 31–6. Essentials of jerk pump and differential needle atomizer injection system; control action and timing; effect of wear on delivery; measurement of delivery under varying conditions of speed and pressure.

PORTABLE POWER PLANTS. Diesel Engines as Portable Power Plants, O. F. Allen. Power v 75 n 3 Jan 19 1932 p 99–101. One of fields for which Diesel engine is particularly suited is portable power plant; in application Diesel has lower fuel cost than gasoline engine, less labor and objectionable noise than has steam unit and is more flexible than electric motor.

SUPERCHARGING. Les possibilities actuelles des moteurs Diesel a quatre temps et a deux temps suralimentés, M. Gautier. Technique Moderne v 24 n 2 Jan 15 1932 p 43–50. Economies effected by supercharging of 4- and 2-cycle Diesel engines; possibilities of different designs illustrated by numerical examples; utilization of exhaust gases.

VIBRATIONS. Practical Experiences With Devices for Damping Torsional Vibrations, E. Sandner and J. Barraja-Frauenfelder. Soc Automotive Engrs—J v 29 n 6 Dec 1931 p 458–64 and (discussion) 464–9. Damping flywheel with hydrostatic coupling permits damping of vibration of shafting even when running in most dangerous speed-ranges of largest engines, and running at all speeds without regard to vibration and without resorting to hand operation of damping device.

DROP FORGING

UPSETTING. Die Forging, F. W. Spencer. Machy (Lond) v 39 n 1001 Dec 17 1931 p 360–3. Drop, machine, and electric-upsetting processes; macrosection of electrically upset valve head. Before Instn Mech Engrs.

FLOW OF FLUIDS

TURBULENT. Turbulence and Mechanism of Resistance on Spheres and Cylinders, F. Ahlborn. Nat Advisory Committee Aeronautics—Tech Memo n 653 Jan 1932 19 p 3 supp plates. Turbulent flow through pipes and around obstacles is analyzed and illustrated by photographs of turbulence on screens and straighteners; reversal of flow and of resistance law on spheres is not explainable by Prandtl's turbulence in boundary layer. From Zeit fuer Technische Physik 1931.

FLOW OF STEAM

PIPES. Charts for Solving Steam Flow Problems, G. B. Massey. Heat and Vent v 29 n 1 Jan 1932 p 34–6. Nomographic charts designed for determining pressure drop in saturated steam when passing through pipe of given diameter, and for determining velocity of steam in pipe when passing certain quantity at given pressure through given diameter pipe.

FLOW OF WATER

ORIFICES. Measurement of Fluid Flow—Tests on Flow of Water Through Orifice Plates, F. V. A. E. Engel. Civ Eng (Lond) v 26 n 306 Dec 1931 p 21–7. Results of experiments carried out by author at City and Guilds Engineering College (Imperial College), London; discharge coefficients for orifices; layout of test plant; impact pressure. Bibliography.

PIPE BENDS. Supplementary Friction Heads in One-Inch Cast-Iron Tees, F. E. Giesecke and W. H. Badgett. Heat Piping and Air Conditioning v 4 n 1 Jan 1932 p 53–6. Review of testing procedure and results in research investigation conducted at Agricultural and Mechanical College of Texas in cooperation with A.S.H.V. E. Research Laboratory for determination of loss of head in pipe tees; application of results to typical case.

MEASUREMENT. Misure di portate negli impianti idroelettrici eseguite col metode Gibson, E. Scimemi. Energia Elettrica v 8 n 12 Dec 1931 p 1029–36. Application of Gibson pressure method for determination of discharge of penstocks of hydroelectric power plants in Northern Italy; comparison of data given by Gibson method with results of current meter gagings.

FURNACES, INDUSTRIAL

HEAT TRANSMISSION. Der Waermeuebergang durch Strahlung in Feuerungen, P. Koessler. Chemische Apparatur v 18 n 22 Nov 25 1931 p 245–8. Contribution to problem of heat transfer by radiation in furnaces.

GEARS

SPUR. Integral Tooth Contact in Spur Gears, K. G. Holst. Am Mach v 76 n 2 Jan 14 1932 p 45–7. Table for outside diameters of standard 14½-deg involute gears for two-pair integral tooth contact and one diametral pitch; cutters for producing special integral contact gears differ from standard ones only as to lengths of teeth and widths of tooth points.

Kritische Zaehnezahlen bei normalen Stirnraedern, Schulze-Pillot. VDI Zeit v 76 n 3 Jan 16 1932 p 57–61. Calculation of critical number of teeth for normal spur gears according to Hertz equation, with particular regard to determination of maximum tooth pressure for different gear ratios and number of teeth.

TESTING. Involute Gear Tooth Testing Instrument. Engineering v 133 n 3442 Jan 1 1932 p 22. Instrument for testing accuracy of contour of involute gear tooth, introduced by David Brown & Sons; intended primarily for checking of repetition work, it is equally useful for testing such special types as master gears.

WORM. Automobile Worm Gears, H. Walker. Automobile Engr v 22 n 289 Jan 1932 p 28–30. Tests of Holroyd-Walker worm gear on Daimler-Lanchester worm-gear testing machine at National Physical Laboratory; maximum efficiency 97.6% under various conditions of speed and power, including maximum speed and load of 86 hp at 2000 rpm; features of Holroyd worm-wheel generators.

GRINDING

DEVELOPMENTS IN. Grinding Applications in Modern Manufacture, F. Horner. Machy (Lond) v 39 n 1005 Jan 14 1932 p 485–9. Recent developments in cylindrical, form, roll, centerless, internal, and surface grinding; examples of wide-wheel operation; components for multiple-wheel cutting; Churchill roll-grinding machine; infeed centerless grinding; ball grinding on centerless machine; Graham cup-wheel system on generating straight, convex, or concave rims; Churchill planetary method of crankpin truing.

INTERNAL. Der Kugelflaechenschliff auf der Innenschleifmaschine, K. Seitter. Werkstattstechnik v 25 n 20 Oct 15 1931 p 469–71. Methods of grinding spherical surfaces by means of internal grinding machines.

GRINDING MACHINES

CHASING THREAD CUTTERS. Chaser Thread-Grinding Machine. Engineering v 133 n 3443 Jan 8 1932 p 34–5. Machine manufactured by Atkins (Peterborough), Ltd. designed in response to demand for accurate formation of thread of chasing cutters by grinding; it is provided with diamond wheel-dressing device, which reproduces contour of thread from much-enlarged former, thereby insuring precise copy to correct scale.

HEAT TRANSMISSION

GRANULAR MATERIALS. Note on Heat-flow Through Granulated Material, J. H. Awbery. Lond Edinburgh and Dublin Philosophical Mag and J Science v 12 n 81 Dec 1931 p 1152–5. Theoretical mathematical discussion of heat flow in aggregate of exactly similar particles, packed in such manner that every one bears same relation to its neighbors as any other.

PIPE—VISCOUS FLUIDS. Die Waermeuebertragung bei zaehen Fluessigkeiten in Rohren, H. Kraussold. Forschungsheft n 351 Dec 1931 p 20. Investigation of heat transfer with viscous fluids in pipes; results of tests; comparison with other research results. Bibliography.

RADIATION. Die Temperaturen technischer Oberflaechen unter dem Einfluss der Sonnenbestrahlung und der naechtlichen Ausstrahlung, K. Schropp. Gesundheits-Ingenieur v 54 n 50 Dec 12 1931 p 729–36. Temperatures of surfaces under influence of radiation of sun and radiation during night; theory of absorption and emission of heat by radiation; heat absorption for white surface, 220,000 to 270,000, and for black surface, 590,000–670,000 cal per hr per sq m.

HEATING

HOT-WATER. Zentrale Warmwasserversorgung die Siedlungswohnung, P. Drexler. Gesundheits-Ingenieur v 55 n 3 Jan 16 1932 p 25–31. Study of costs of operation and of some engineering features of central hot water heating systems, particularly adapted to suburban real estate developments; automatic regulation of tap water temperature; combination of heating with hot-water supply; central hot water supply.

HYDRAULIC TURBINES

KAPLAN. Om Kaplanturbinens konstruktion och foerdelar, L. Helenius. Tekniska Foereningens i Finland Foerhandlingar v 51 n 12 Dec 1931 p 376–83. Design and operating principles of Kaplan turbines, with data on Swedish and Finnish installations.

NEW BRITISH TYPE. New Water Turbine. Water and Water Eng v 34 n 399 Jan 20 1932 p 18–9. Features of British patented water turbines, for either high or low heads, utilizing streamlined means for directing water in such manner that its propulsive effect is concentrated more especially upon outer portions of blades, or those parts farthest from turbine shaft, where application of turning moment is most effective.

PELTON. Some Large Pelton Wheels. Engineer v 153 n 3965 Jan 8 1932 p 48–50. Machines for Shanan generating plant of Uhl River project in Punjab, India, being made to designs of Boving and Co., by Markham and Co.; each unit comprises single-runner Pelton wheel, with single jet, overhung on end of generator shaft; capable of developing 17,000 hp continuously when running at speed of 428.5 rpm under effective head of 1668 ft.

Water Turbines for Shanan Power Station, Punjab. Engineering v 133 n 3445 Jan 22 1932 p 95–8. Turbines supplied by Boving and Co., London, are of Pelton overhung type, four in number, with single runners and single jets; effective head will be 2001 ft; runners are 78¾ in. in diam, with 22 buckets cast in pairs, and are claimed to most powerful Pelton runners so far built in England; disk of runner is of forged steel; buckets are 23⅛ in. wide inside and made of steel.

HYDROELECTRIC POWER PLANTS

PUMPED STORAGE. Herdecke: Largest Pumped-Storage Hydro-Electric Plant, W. Netoliczka. Power v 75 n 5 Feb 2 1932 p 160–3. Four 48,000-hp, horizontal-shaft turbines operate at 506 to 534 ft head; three of units consist of turbine, generator and pump, fourth unit has no pump; pumps are largest ever constructed; constructional and operating details.

INDUSTRIAL MANAGEMENT

COST ACCOUNTING. What About 1932 Profits?—Answer Is Reduction of Costs, O. E. Knoeppel. Iron Age v 129 n 3 Jan 21 1932 p 217–20. After two years of diminishing profits or actual losses, attention will be focused on increasing sales volume as well as decreasing costs; in budgeting for 1932, author used chart based on percentage rather than dollars, in order to illustrate pernicious influence of fixed costs on profits.

MOTION STUDY. See What Motion Study Did to Plant Layout, F. J. VanPoppelen. Factory and Indus Mgmt v 82 n 6 Dec 1931 p 797–9. Review of activities of plant layout department of Cadillac Motor Car Co., Detroit, Mich.; old and new layouts.

PRODUCTION CONTROL—RECORDS. Arbeitsvorbereitung zur Werkstoffwahl bei der Konstruktion, E. Eichwald. Maschinenbau v 10 n 20 Oct 15 1931 p 648–53. Work preparation and selection of raw materials; efficient layout of record system to be used by designer to facilitate selection of raw materials for parts for individual jobs and mass production.

INTERNAL-COMBUSTION ENGINES

COMBUSTION. Neue Untersuchungen ueber die Rationalisierung des Kraftstoffverbrauches im Verbrennungsmotor. Automobiltechnische Zeit v 34 n 36 Dec 31 1931 p 803–7. Experimental investigation by AEG to reduce fuel consumption of internal-combustion engines by improving combustion process; photographic recording of atomization obtained by carburetor and fuel injection.

FUELS. Produits de remplacement des essences de pétrole et des gas oils, A. Grebel. Génie Civil v 99 n 24 and 25 Dec 12 1931 p 597–601 and Dec 19 p 626–9. Progress in utilization of various coal by-products, wood and alcohol for internal-combustion engines, particularly automotive types; interpretation of statistical data for France.

Utilizing Low-Grade Fuels in Otto-Cycle Engines, M. J. Zucrow. Motive Power v 3 n 1 Jan 1932 p 9–12 and 42. After discussing fundamental requirements of satisfactory fuel system for Otto-cycle engines and reviewing briefly characteristics of gasoline carburetion system, author considers various factors that affect design of carburetion equipment for burning low-grade fuels and presents with illustrations and test data description of such equipment for heavy-duty engines.

MANUFACTURE. Metallurgical Problems of Quantity Production, E. C. Dickinson. Machy Market n 1623 Dec 11 1931 p 17–8. Main problems which confront quantity production metallurgist who is associated with manufacture of complex units; choice of correct material; inspection of incoming materials; heat treatment; manufacturing difficulties; methods of testing. Before Junior Instn Engrs.

PROGRESS. Oil and Gas Engine Progress in 1931. Power v 75 n 1 Jan 5 1932 p 19–22. In spite of decrease in oil and gas engine orders in 1931 as compared to 1929 and 1930, these two industries have suffered less than have many other machine industries, and in power field have slightly increased their relative position.

WASTE HEAT UTILIZATION. Determination of Exhaust Heat in Internal Combustion Engines, L. R. Underwood. Engineering v 133 n 3444 Jan 15 1932 p 63–5. It is concluded that exhaust-gas temperature may be accurately measured, provided that thermocouples are carefully placed and precautions taken to eliminate errors due to radiation; cause of apparent discrepancy between measured and calculated heat in exhaust.

[See also *Oil Engines.*]

LATHES

AUTOMATIC. Der Starrautomat "Loewe-Mulka" mit neuartigem Zerspanungsverfahren, M. Kronenberg. Maschinenbau v 10 n 24 Dec 17 1931 p 733–8. Development of automatic round shape cutting machine employing four broad cutters at right angles revolving around work and moving in radial direction toward center; design and calculation of movement; chip-forming process; testing.

CUTTING PRESSURE—MEASUREMENT. Beitrag zum Bau von Drehbankmesssupporten mit Hochdruckmessdosen, A. Wallichs and H. Schoepke.

Werkzeugmaschine v 35 n 22 and 23 Nov 30 1931 p 445–8 and Dec 15 p 472–4. Design and operating principles of equipment and instruments for measuring cutting pressure.

MANUFACTURE. Die Herstellung von Leitspindeln fuer Drehbaenke, W. Iwascheff. Werkstattstechnik v 25 n 19 Oct 1 1931 p 449–53. Manufacture of lead screws with particular regard to accuracy and tolerances; relative merits of different threads; methods for measuring accuracy.

LOCOMOTIVES

ARTICULATED. Western Pacific Single-Expansion Articulated Locomotives. Ry Mech Engr v 106 n 1 Jan 1932 p 14–7. Six 2–8–8–2 types built by Baldwin hauling fruit trains of 3750 tons through Feather River Canyon, purchased to replace 2–6–6–2, 2–8–2 and 2–8–0 type locomotives previously used double-heading to handle equivalent tonnage; cylinders 26 by 32 in.; driving wheels 63 in.; steam pressure 235 lb to sq in.; total engine wheelbase 61 ft 5 in.; total weight of engine in working order 665,100 lb.

DIESEL-ELECTRIC. British View of Diesel-Electric Locomotive, A. A. Gill. Diesel Power v 10 n 1 Jan 1932 p 27–8. Comparative analysis of steam and Diesel-electric locomotives; fuel consumptions on test bed; Beardmore high-speed Diesel engines; service results.

Engineering Features of Three-Power Locomotives, F. H. Brehob and F. H. Craton. Elec Eng v 51 n 1 Jan 1932 p 9–13. Locomotives contain Ingersoll-Rand 300-hp direct-fuel injection oil engine coupled to 200-kw generator and 301-kwh storage battery for internal drive as well as 600 v (3rd rail) for N. Y. C. and 3000 v (trolley) for D. L. & W. for external drive; specification data and operating characteristics.

Ueber Diesellokomotiven unter besonderer Beruecksichtigung der Versuchsergebnisse der Dieseldruckluftlokomotive der Deutschen Reichsbahn, H. Nordmann. Glasers Annalen v 109 n 11 Dec 1 1931 p 93–100. Advantages of Diesel over steam operation with particular regard to performance of compressed-air locomotive of German State Railroad.

GASOLINE—SWITCHING. Petrol-Driven Shunting Locomotives, Netherlands Railways. Ry Gaz v 56 n 2 Jan 8 1932 p 51–3. "Locomotors" are designed and constructed so as to permit dual duties of shunter and driver being performed by one person; constructional and operating characteristics.

HIGH-PRESSURE—FRANCE. Locomotive à haute pression, M. A. Parmantier. Revue Générale des Chemins de Fer v 51 n 1 Jan 1932 p 10–47 3 supp plates. Design and operating characteristics of high-pressure locomotive with Schmidt superheater of Compagnie des Chemins de Fer de Paris à Lyon et à la Méditerranée; interpretation of dynamometer test results and indicator diagrams; thermodynamic efficiency.

LUBRICANTS

CUTTING. Cutting Fluids and Their Applications, J. D. Roney and G. L. Sumner. Am Mach v 76 n 2 Jan 14 1932 p 50–3 and 67. Proper use of cutting lubricants for principal metals, with particular regard to water compounds and lard oil combinations; cutting fluids application chart.

MACHINE TOOLS

ADAPTING TO NEW WORK. Adapting Machine Tools to New Jobs, J. P. Lannen. Machy (N. Y.) v 38 n 5 Jan 1932 p 333–5. New application of single-purpose, planer-type milling machine; multiple-spindle drilling machines arranged for tapping; hydraulic feeding mechanisms applied to two machines; honing machine adapted for multiple chamfering operation.

DESIGN—GERMANY. Tendencies in German Machine-Tool Design. Engineering v 133 n 3442 Jan 1 1932 p 5–7. Task of designer is facilitated by work of metallurgist, such as introduction of Widia and similar tool steels; question of rigidity has received particular attention; castings being replaced by welded-steel structures in grinding machines; larger machine tools arranged for direct drive; hydraulic transmission systems; directions in which waste time has been reduced.

MACHINERY

COSTS. Naeherungsverfahren zur Selbstkostenvorrechnung, C. Klotzsch. Maschinenbau v 10 n 24 Dec 17 1931 p 738–40. In case cost of certain piece of machinery is to be calculated for quotation purposes, and exact cost is not at hand, approximate cost may be estimated by interpolation from other types of different sizes from same series; exemplification.

MANGANESE STEEL

PROPERTIES. Mechanische Eigenschaften von geschmiedetem und gegossenem Stahl mit hohem Mangangehalt, P. Bardenheuer and G. Schitzkowski. Mitteilungen aus dem Kaiser-Wilhelm-Inst fuer Eisenforschung zu Duesseldorf v 13 n 20 report n 191 1931 p 237–45. Investigation of mechanical properties of forged and cast steel with high manganese content (1 to 3%); influence of testing temperature in range of minus 20 to plus 100 C.

MEASURING INSTRUMENTS

KINETIC. La cinetique des appareils mécaniques de mesure, F. H. Van Den Dungen. Annales de l'Assn des Ingénieurs sortis des Ecoles Spéciales de Gand v 21 series 5 1931 n 1 and 2 p 51–96 and p 151–82. Theoretical mathematical analysis of kinetics of measuring instruments with particular regard to periodic and quasi-periodic movements, damping effects, resonance, static, and kinetic reaction; theory of apparatus using ballistic principles.

METALS

COLD-ROLLING. Cold Rolling Strips by Steckel Process. Iron Age v 129 n 2 Jan 14 1932 p 168–71 and 214. Equipment employed and outline of process developed by A. P. Steckel; process aims to preserve ductility; general arrangement and details of mill.

COLD-WORKING. Metal Rolling in Mass Production, J. R. Cornelius. Am Mach v 76 n 1 Jan 7 1932 p 2–7. Design and operating principles of cold rolling machines with particular regard to English practice; machines to roll castings and heavy forgings; rolling of round-belt V-pulley, trolley wheel, steel stud, and corrugated tube.

DEFORMATION. La détermination des caractéristiques d'allongement visquex des métaux a chaud, G. Ranque and P. Henry. Académie des Sciences—C R v 193 n 22 Nov 30 1931 p 1061–3; see also Génie Civil v 51 n 25 Dec 19 1931 p 630–1. Description of apparatus for determination of characteristics of plastic elongation of metals at high temperatures.

Mechanik der spanlosen Formung Walzen, Pressen, Ziehen usw, G. Sachs. VDI Zeit v 76 n 3 Jan 16 1932 p 49–54. Review of German experimental and theoretical studies of mechanics of chipless forming, including processes of rolling, pressing, drawing, etc.; energy of deformation and friction; plastic resistance to hot and cold working; determination of friction, wire drawing, deep drawing, stamping, etc.

FATIGUE. Die Drehwechselfestigkeit verschiedener Staehle bei gleichzeitiger statischer Beanspruchung, W. Herold. Maschinenbau v 10 n 20 Oct 15 1931 p 637–43. Torsional fatigue strength of various steels with simultaneous static stressing; relations between torsional vibration strength, bending vibration strength, and static strength values; torsional fatigue strength of ground specimens with notch; fatigue yield limit and its dependence on heat treatment.

HARDENING. On Simple Model Explaining Hardening Effect in Poly-Crystalline Metals, H. Hencky. J of Rheology v 3 n 1 Jan 1932 p 30–6. Strain-hardening observed in polycrystalline metals is also present in elastic state, but is hidden by comparatively big value of modulus of shear; simple microstructural model is described and statistically treated; model shows all features observed in tension- and compression-test, and explains Bauschinger-effect and brittleness after plastic strain.

TEMPERATURE EFFECT. Effect of Temperature on Some of Physical Properties of Metals, F. C. Lea and C. F. Parker. Engineering v 133 n 3442 and 3443 Jan 1 1932 p 23–6 and Jan 8 p 54–5. Effect of temperature and stress upon metals; phenomenon and measurement of positive creep in relation to temperature and stress; secondary effects of importance, especially in cases where metals are subjected to high temperature conditions for long periods. Before Brit Assn.

TESTING MACHINES, GERMAN. Neuere Pruefmaschinen und deren praktische Handhabung, O. Beckmann. Zeit fuer die gesamte Giessereipraxis v 52 n 48, 49, 50 and 51–2 Nov 29 1931 p 403–5, Dec 6 p 414, Dec 13 p 419–21, Dec 23, p 429–33. Examples of new materials-testing machines for static and dynamic investigation of metals, and their applications.

METALS CUTTING

CUTTING PRESSURE. Ergebnisse der Schnittdruckmessung bei der Zerspanung verschiedener Stahlsorten, W. Dick. Stahl und Eisen v 52 n 1 Jan 7 1932 p 17–18. Results of measurement of cutting pressure in cutting of different varieties of steel.

MILLING

DYNAMIC STUDY OF PROCESS. Dynamische Untersuchungen des Fraesvorganges, F. Eisele. Berichte ueber Betriebswissenschaftliche Arbeiten v 7 1931 41 p. Dynamic investigation of milling process with particular regard to determination of laws for three cutting pressure components and their fluctuations; tests with milling cutters on different materials and at various table feeds, cutting speeds, and cutting depths; rules for preventing vibration.

MOLDS, FOUNDRY

MOLD-WALL THICKNESS. Ueber den Einfluss der Formwandbeschaffenheit auf die Ausbildungsform und Menge des Graphitgehaltes im Grauguss, H. Nipper and E. Piwowarsky. Giesserei v 19 n 1–2 Jan 8 1932 p 1–3. Influence of thickness of mold wall on nature and volume of graphite content in gray cast iron; with wall thickness of 185 mm, surface quality has no influence on graphite in casting at normal molding temperatures.

NITRIDATION

DEEP NITRIDING. Deep Nitriding by Program Control, J. W. Harsch and J. Muller. Metal Progress v 21 n 1 Jan 1932 p 74–6 and 94. Factors influencing nitriding process; materials in reaction zone; temperature at which reaction is carried out; time during which reaction proceeds; rate and manner of flow of active chemical.

MACHINE-TOOL APPLICATIONS. Neuere Erfahrungen mit Nitrierstahl, insbesondere im Werkzeugmaschinenbau, W. Haufe and F. Bruehl. Maschinenbau v 10 n 19 Oct 1 1931 p 606–7. Recent experiences with nitrided steel, particularly in construction of machine tools; practical examples illustrate advantageous applications of nitrided steel to spindles and gears of machine tools.

OIL ENGINES

RUSTON AND HORNSBY. Some Comparative Tests on Ruston Heavy-Oil Engine. Gas and Oil Power v 26 n 315 Dec 3 1931 p 365–6. Buechi supercharged engine which Ruston and Hornsby, Ltd., Lincoln, recently supplied to Ashford U. D. Council, was subjected to comparative tests by W. A. Tookey, with and without pressure induction, before delivery; value of Buechi system of supercharging clearly established.

PLATES

STRESSES. Die Knickspannungen von eingespannten rechteckigen Platten, F. Schleicher. Mitteilungen aus den Forschungsanstalten v 1 n 8 Dec 1931 p 186–93. Mathematical investigation of buckling stresses in rectangular plates, in which accuracy of Hooke's law is assumed.

POWER GENERATION

EFFICIENCY, GROWTH IN. Greater Efficiency in Steam—Now 1.56 lb of Coal per Kw-Hr. Elec World v 99 n 1 Jan 2 1932 p 63–5. Entire production from steam rose from 27,248,000,000 kwhr in 1920 to 42,264,000,000 in 1925 and to 62,915,000,000 kwhr in 1930; this was maximum; there was decrease of about 1,000,000,000 in 1931; figures are for all public utilities, not for central stations exclusively; also, they include small amounts generated by internal-combustion engines, but not enough appreciably to affect conclusions.

POWER-PLANT ENGINEERING

EUROPEAN. European Units Tend Toward Larger Size. Power v 75 n 1 Jan 5 1932 p 36–8. Underfeed stokers and chain grates continue to predominate, although pulverized fuel makes headway where economics justify; both boiler and turbine units gradually grow in capacity; pumped-storage hydro plants as economical means of supplying peak-load capacity continue to increase; developments up to 600,000 kwhr storage capacity are now in operation.

PROGRESS. Progress in Prime Movers in 1931. Engineer v 153 n 3964 Jan 1 1932 p 9–11. Review of progress; Benson boiler; binary-fluid systems; coal-dust engines; hydraulic engineering; seawater power.

PRESSURE VESSELS

WELDING. Present Use of Welding in Pressure Vessel Field, W. Spraragen. Iron Age v 129 n 2 Jan 14 1932 p 161–5. Recently liberalized regulations of boiler code committee of Am Soc Mech Engrs, permitting use of welding in pressure vessel field, means much for future of welding; achievements of three American companies producing welded pressure vessels; six fundamental factors in welding are laid down.

PULVERIZED COAL

FIRING. Pulverizer Sizes and Installation Details From Operator's Viewpoint, C. F. Hawley. Power v 75 n 3 Jan 19 1932 p 96–7. General considerations of installation and equipment details of pulverized fuel firing; control equipment.

PUMPING PLANTS

DIESEL. Brantford Uses Diesel Engines in

New Waterworks Station. Power House (Eng) v 25 n 11 Nov 1931 p 41–3. Three Diesel engines maintained as stand-by unit and also used for taking peak load from hydro when required in Brantford, Ont.; details of coagulating basin; engine particulars; lubrication system.

EQUIPMENT. Selection and Operation of Centrifugal Pumps, R. B. Hall and S. H. Smith. Am. Water Works Assn—J v 24 n 1 Jan 1932 p 57–61. Necessity of high initial efficiency; maintaining efficiency; necessity of measuring pump output; advice to plant manager; study of demand curves; elements in purchase.

PUMPS

AIR-LIFT. Cause of Fluctuations in Rising Mixtures of Gas and Liquid, J. Versluys. J of Rheology v 3 n 1 Jan 1932 p 3–15. Outline of theory of existence of unstable zone in rising mixtures of liquid and gas, between zones of mist and foam; limits of foam and mist conditions; application of theory to such phenomena as rise of oil in wells, air-lift and gas-lift pumping, intermittency of hot and gaseous springs, also of volcanic action.

CENTRIFUGAL—GOVERNORS FOR. Automatic Governor for Centrifugal Pumps. Engineer v 153 n 3967 Jan 22 1932 p 108. Governor called "Pumreg" can be adjusted to determine and control max. power which is absorbed by centrifugal pump; marketed by Holden and Brooke.

INTERNAL-COMBUSTION. Humphrey Pump and Installation of Two Sixty-Six Inch Units at Cobdogla, River Murray, J. I. McLauchlan. Instn Engrs Australia—J v 3 n 12 Dec 1931 p 413–26. Theory of Humphrey internal-combustion pump in which force exerted by explosion of mixture of inflammable gas and air acts directly on surface of water, forcing it to elevated position; details of combustion head, interlocking operator, ignition gear, valves, and gas-generating plant; operating results and costs.

PYROMETERS

ARDOMETER. Temperaturmessung beim Haerten von Federn, W. Funck and H. H. Miething. Maschinenbau v 10 n 19 Oct 1 1931 p 617–8. Temperature measurements in hardening of springs; accurate results obtained by use of "Ardometer"; satisfactory agreement with calorimetric measurements.

RAIL MOTOR CARS

DIESEL-ELECTRIC. New 250 h.p. Oil-Electric Rail-car: Armstrong-Whitworth Standard. Locomotive v 38 n 473 Jan 15 1932 p 8–11; see also Tramway and Ry World v 71 n 3 Jan 14 1932 p 13–7. Design, construction and operating details of high-speed Diesel oil engines for use in rail motor cars to run with reliability and low maintenance cost; diagrams of general arrangements and dimensions; electric equipment.

OIL-ELECTRIC. 250-H.P. Oil-Electric Rail Coach. Engineering v 135 n 3442 Jan 1 1932 p 10–2. Coach built by Armstrong-Whitworth equipped with 250-hp engine, of standard Armstrong-Sulzer locomotive type, having 6-cylinders; electric transmission consists of d-c generator, driven by engine, and supplying current to two truck traction motors geared to axles of one.

PROPELLER-DRIVEN. Versuchsfahrten mit einem schnellfahrenden Schienefahrzeug mit Luftschraubenantrieb, F. Weenwald and W. Feucht. Zeit fuer Flugtechnik und Motorluftschiffahrt v 22 n 22 Nov 28 1931 p 667–71. Interpretation of experiments with high-speed rail motor car with propeller drive, with particular regard to installation for testing airplane propellers.

REFRIGERATION

LOW-TEMPERATURE. Advantages of CO_2-Ammonia System for Low-Temperature Refrigeration, W. R. Kitzmiller. Power v 75 n 3 Jan 19 1932 p 92–4. Split system has played important role in freezing and preservation of fruits, meats, ice creams, fish and other foods, and is being extended into other fields, such as process work in refineries, research work in laboratories and experimental work in industrial plants; diagram and operation of split-stage system; automatic control.

RESEARCH

ENGINEERING—GREAT BRITAIN. Department of Scientific and Industrial Research. Engineer v 153 n 3966 Jan 15 1932 p 78–9 and editorial comment p 73–4. Review of report of Advisory Council 1930–31; natural growth of department's organization; its flexibility; contact with industry; application of new inventions; conclusions.

ROLLING MILLS

SHEET THICKNESS AT CENTER. Why Sheets Are Thicker at Center, W. H. Melaney. Blast Furnace and Steel Plant v 20 n 1 Jan 1932 p 61–3. Theory of cause of greater thickness at center; Lauth's 3-high mill; elastic restoration; molecular flow.

ROLLS

GRINDING. Grinding of Rolls for Rolling Mills, H. J. Wills. Iron Age v 128 n 27 Dec 31 1931 p 1683–5 and 1726. Roll grinding and finishing in sheet steel, strip mill, tin plate, steel plate, and bar, sheet brass, copper, and aluminum industries; roll grinding machines; wheels for roll grinding; coolant preparation.

SCALES

TRACK. Replacement of National Bureau of Standards Track Scale Test Car No. 1. Scale J v 18 n 4 Jan 1932 p 3–4. Design, construction and operating features of Bureau of Standards new track scale test car purchased from A. H. Emery Co., Stamford, Conn.; car hoisting and weighing equipment; end, sectional plan, and longitudinal plan views.

SCREW MACHINES

COLD-ROLLING. Die Kaltgewindewalzmaschinen, ihre Entwicklung und Arbeitsweise, W. Reichel. Werkzeugmaschine v 35 n 21 Nov 15 1931 p 425–30. Screw-thread cold rolling machines, their development and operating principles; design and performance data of German and American makes.

MULTI-SPINDLE AUTOMATIC. Small Capacity Multi-Spindle Automatic. Machy (Lond) v 39 n 1005 Jan 14 1932 p 503–5. Four-spindle machine for bars up to $1^3/_4$ in. diam developed by B. S. A. Tools, Ltd., Birmingham; tool slide also arranged that it is possible to perform with four spindles work that normally demands 5- or 6-spindle machine; floor space 17 ft by 4 ft 6 in. and weight of $4^1/_2$ tons.

SCREW THREADS

IMPROVED THREAD. Ueber eine neuartige Schraubenverbindung, E. Jaquet. Schweizerische Bauzeitung v 98 n 17 Oct 24 1931 p 207–10. Design of screw with improved stress distribution obtained by undercutting of thread in female parts.

MEASUREMENT. Die Pruefung konischer Innengewinde, A. Werner, G. Bochmann and R. Lehmann. Zeit fuer Instrumentenkunde v 1 n 52 Jan 1932 p 14–19. Methods and equipment for measuring internal dimensions of ring gages for taper threads developed by Physikalisch-Technische Reichsanstalt, according to specifications of American Petroleum Institute.

STRENGTH. Gewindetoleranzen und Festigkeit von Schraubenverbindungen, G. Berndt. Maschinenbau v 10 n 19 Oct 1 1931 p 610–4. Thread tolerances and strength of screwed joints; establishment of principal standards for Whitworth thread of 1-in. diam under basis of pull, torsion and fatigue tests; most economical nut height should be 0.8 of thread diam.

SHAFTS

GROUP DRIVE. Power Analysis in High-Speed Group Drives, R. W. Drake. Maintenance Eng v 90 n 1 Jan 1932 p 12–3. Analysis of group-drive transmission losses for battery of eight machines driven from lineshaft 80 ft long by 50-hp motor; transmission equipment required for given drive at different group shaft speeds; practical review of several specific examples of transmission losses.

SHEARS

ELECTRIC DRIVE. Elektrisch Betriebene Scheren und Saegen fuer Walzwerke, O. Pollok. Werkstattstechnik v 25 n 23 Dec 1931 p 536–9. Requirements for economical application of electric drive to shears and saws in rolling mills; performance data for representative German makes.

SPRINGS

LAMINATED. Untersuchungen an Blattfedern, H. Stark. VDI Zeit v 75 n 51 Dec 19 1931 p 1521–6. Progress report of Spring Committee of VDI on graphic experiments; stress distribution in vertically loaded leaf springs and comparison with data obtained from various laminations; satisfactory agreement of calculation with experiments.

STEEL FOR—PROPERTIES. Practical Application of X-Ray Diffraction Methods in Study of Quench and Temper Structures of Carbon Spring Steels, N. P. Goss. Am Soc Steel Treating—Trans v 19 n 2 Dec 1931 p 182–92. Ill effects due to improper quenching cannot be removed by tempering; type of grain structure developed depends upon chemical composition, thickness and shape of specimen, temperature quenching medium, kind of medium (water, oil, etc.).

STEAM

HEAT STORAGE. Thermal Storage—IV, E. G. Ritchie. Steam Engr v 1 n 4 Jan 1932 p 159–62. Consideration of use of large quantities of steam in heavy engineering industries e.g. drop stamps, steam hammers, steam pressures, etc.; extent to which manufacturing capacity of plants may be handicapped by fluctuating steam pressure; indicated diagram illustrating effect of steam pressure variations on performance.

STEAM ENGINES

MARINE—EFFICIENCY. Marine Engine. Engineering v 133 n 3445 Jan 22 1932 p 105–6. North East Coast Institution of Engineers and Shipbuilders organized discussion on improved marine steam reciprocating engines, and whether their performance justified their extra cost; review of written contributions; general discussion of question by J. N. Hendry; one point brought out is wide gap between performance of standard marine and land engine.

THERMODYNAMICS OF. Factors Affecting Thermal Efficiency of Steam Engine—II, S. Miall. Ry Eng v 52 n 623 Dec 1931 p 488–90. Theoretical considerations and practical difficulties in connection with raising locomotive efficiency are discussed, and solutions indicated.

STEAM HEATING PLANTS

FUEL RATES. Method for Determining Fuel Burning Rates in Heating Boilers Fired by Automatic Devices, R. C. Cross. Heat and Vent v 29 n 1 Jan 1932 p 41–2. Rate of fuel burning in heating boiler influenced by several factors such as fuel characteristics, method of burning, boiler performance, etc., but is fundamentally determined by radiation load necessary to compensate for heat loss of building; discussion assumes that radiation of proper amount is known factor.

INSULATION. Der Warmeschutz in Heizungsanlagen, H. Schacht. Gesundheits-Ingenieur, v 54 n 52 Dec 26 1931 p 757–64. Theoretical mathematical discussion of principles of heat-insulation engineering; simplified method of computing heat losses; examples from heat-insulation practice.

STEAM PIPE LINES

WELDING. Pipe Welding for High Pressure Steam Service, F. W. Martin. Ry J v 37 n 12 Dec 1931 p 21–5. Application of arc and acetylene welding practices in high-pressure steam pipe lines; specific welding applications. Before Int Acetylene Assn.

STEAM POWER PLANTS

COAL HANDLING. Coal and Ashes Handling at Chicago Board of Trade Building, E. A. Wendell. Universal Engr v 55 no 2 Feb 1932 p 24–6. Design, construction, and operating characteristics of materials-handling system installed in Chicago Board of Trade Building; drawing showing arrangement of coal-handling system.

DESIGN. Trend of Power Plant Design in Germany. Power v 75 n 7 Feb 16 1932 p 251. Status of high steam pressures and temperatures and Benson and Loeffler boilers; combustion-air temperatures with stokers and pulverized fuel; high-speed turbines; handling peak loads.

EFFICIENCY. Studies in Steam Costs That Have Produced Substantial Economies. Power House (Eng) v 25 n 11 Nov 1931 p 34–6. Review of economies resulting from general inspection, maintenance and repair of power plant; coal selection and buying; labor and repair costs; flue gas temperature.

FRANCE. La centrale de Vitry-Sud de l'Union d'électricité, Emanaud. Technique Moderne v 24 n 2 Jan 15 1932 p 33–40. Vitry-Sud lower plant in Paris will be put in service with 10,000-kw installed capacity; second part also with 110,000-kw capacity will be ready later in 1932; article discusses boiler house with 35 kg per sq cm, 450 C, Babcock and Wilcox boilers; cross-sectional drawings; notes on generators.

FUEL. Curtailments in Operating Expenditure Increase Efficiency of Fuels Utilization. Power v 75 n 1 Jan 5 1932 p 11–3. Consumption of three basic fuels, coal, fuel oil, and natural gas, has declined with curtailed industrial activity of past year, natural gas having been affected less than others; developments in equipment include 69-tuyère stoker burning over 28 tons per hr, pulverizer with capacity of 50 tons per hr and advances in equipment design and in operating efficiency.

GERMANY. Modern Super-Pressure Steam Operation, D. Brownlie. Steam Engr v 1 n 4 Jan 1932 p 156–9. Details of high-pressure boiler installation in Mannheim Power Station; section through 7000-kw Brown-Boveri turbine; latest design of Hanomag boiler under construction for evaporating 308,560 lb per hr.

GREAT BRITAIN. Brighton Power Station. Power Engr v 27 n 310 Jan 1932 p 15–20 and 4. General description of Corporation Electricity Works, with special reference to recent developments; plan of turbine and boiler houses; layout of Brighton 8000-volt 3-phase system; switchgear and boiler house equipment.

INDUSTRIAL POWER COSTS IN. Calculating Steam and Power Costs in Industrial Plants, H. J. Byrne. Power v 75 n 4 Jan 26 1932 p 140–4. Outline of breaking-down process in determining unit costs of energy and heat; two simple methods of supplying steam to manufacturing process; flow diagram of assumed industrial plant supplying power and steam for manufacturing purposes; distribution table of power, heat and costs.

Management Control of Power Plant Costs, G. A. Holmes. Power House (Mgmt) v 25 n 12 Dec 1931 p 18–21. Methods of management control of power plant costs; preparation of management records; use of graphs; 1929 performance and cost graph; type of records required.

LOW-PRESSURE. Economic Steam Conditions in Industrial Plants Viewed From Low-Pressure End—I and II, F. Johnston-Taylor. Power House (Eng) v 25 n 11 Nov 1931 p 53–5; also Power House (Mgmt) v 25 n 12 Dec 1931 p 31–4. Practical review of factors involved in low-pressure steam; choice of equipment; extraction engines; governing engines; double exhaust valve idea; engines working intermittently; constant pressure system; governing of turbines.

PULVERIZED-COAL. Betriebserfahrungen an einem 42-at Grosskessel, E. Pfleiderer. VDI Zeit v 75 n 50 Dec 12 1931 p 1497–1502. Characteristics of pulverized-coal boiler at nitrogen plant, Oppau bei Ludwigshafen; data collected during 3½ years pertaining to water-cooled grate, feedwater treatment, combustion chamber, cleaning of flue gas; etc.; evaporation tests with different kinds of coal.

Distribution of Pulverized Fuel for Metal Working, F. S. O'Neil. Power Plant Eng v 36 n 4 Feb 15 1932 p 162–3. Design and operating features of pulverizing plant installed by Whiting Corp., Harvey, Ill., at Ewart Plant of Link-Belt Co. in Indianapolis, Ind.; automatic distribution control; plan of coal preparation and distribution system.

New Brazil Plant Burns Low-Grade Coal at High Efficiency, C. H. S. Tupholme. Combustion v 3 n 6 Dec 1931 p 23–5, 33 and 36. Features and layout of steam-electric power plant installed for city of Porto Alegre, Brazil; design, construction and operating characteristics of pulverized fuel system of firing for burning local lignite of low heating value and containing 35–40% ash, 8–14% moisture and considerable stone and pyrites; figures are given on mill maintenance, power costs and amortization charges.

REHABILITATION. Weighing Evidence Concerning Plant Changes, O. H. Henschel. Power Plant Eng v 36 n 1 Jan 1 1932 p 46–7. Economic problems involved in plant rehabilitation; table giving life and depreciation for power equipment.

UNITED STATES. Important Steam Plants Put Into Operation and Under Construction. Power v 75 n 1 Jan 5 1932 p 4–10. Two mercury-vapor plants to operate at higher pressure and temperature than existing plant, two outdoor plants and additional high-temperature units are high spots of 1931 in steam-power generation; table giving equipment specifications for steam plants placed in operation or under construction during 1931.

STEAM TURBINES

DESIGN. Progress in Steam Turbine Design. Power v 75 n 1 Jan 5 1932 p 17–8. Continues toward higher steam temperatures, greater capacity high-speed unit and tandem compounding in large-size machines; two mercury turbines, double capacity of unit now in operation, have been ordered for power plant of G. E. Co. at Schenectady, N. Y.

Brown Boveri Steam Turbines. Power Engr v 27 n 311 Feb 1932 p 48–51. Outline of design characteristics incorporated in turbine constructed by Brown, Boveri and Co., Switzerland; features of single-cylinder power-station condensing turbines.

EFFICIENCY. Efficiency Ratio. Engineering v 133 n 3443 Jan 8 1932 p 30–1. Examples are cited to show that efficiency ratio provides but very imperfect basis for comparing relative merits of steam turbines regarded as hydraulic machines.

HIGH-PRESSURE. High Pressures and Temperatures for Steam Prime Movers, O. Wiberg. Engineering v 133 n 3442 Jan 1 1932 p 27–8. Results of analysis of certain tests of materials conducted by Stal Turbine Co., of which author is chief engineer; large number of steels and alloys were tested.

STEEL

CHROMIUM. See *Chromium Steel.*

COLD-WORKING. Structure of Cold-Drawn Tubing, J. T. Norton and R. R. Hiller. Am Inst Min and Met Engrs—Tech Publ n 448 for mtg Feb 1932 14 p. Tubing samples made of steel having carbon content of 0.10 to 0.20%, and drawn on standard type of draw bench; X-ray method of investigation; structure is independent of method of reduction, and depends only upon dimensional changes during reducing process.

EMBRITTLEMENT. Ueber die Laugenbruechigkeit des Stahles—I and II, F. Hundeshagen. Chemiker-Ztg v 56 n 1, 2 and 4 Jan 2 1932 p 4–5 Jan 6 p 17–8 and Jan 13 39–40. Investigation of caustic embrittlement of steel; American theory of cause of embrittlement; German tests and theory; formation of intercrystalline cracks; investigation of Parr's tests; preventive measures.

HARDENING. Magnetic Hardening of Steel, E. G. Herbert. Engineering v 133 n 3444 Jan 15 1932 p 81. Letter to editor referring to brief editorial comment on May 19 1931 issue of same journal of author's paper before Royal Society; results of further research with special reference to invention of secondary or stabilizing magnetic process for rendering permanent any selected phase of fluctuations set up by rotary magnetic process or by thermal or mechanical means.

Zur Theorie und Praxis der Stahlhaertung, F. Wever. Archiv fuer das Eisenhuettenwesen v 5 n 7 Jan 1932 p 367–75 and (discussion) 375–6. Theory and practice of steel hardening; cooling speed-concentration diagram of transformation temperature in iron-carbon system; speed of transformation of austenite in relation to temperature and composition as basis for explanation of hardening and tempering structures.

HEAT TREATMENT. Heat-Treating Methods and Costs, E. F. Davis. Soc Automotive Engrs—J v 29 n 6 Dec 1931 p 474–5 and 478. Development of continuous automatic methods for annealing, carburizing, and hardening steel; choice between sources of heat on basis of results; developments that will provide accuracy in forgings and eliminate scale.

MANGANESE. See *Manganese Steel.*

SPRING. See *Springs.*

TEMPERATURE EFFECT. Strength at High Temperatures of Cast and Forged Steel as Used for Turbine Construction, H. J. Tapsell and A. E. Johnson. Dept Sci and Industrial Research—Eng Research Special Report n 17 1931 33 p. Short-time tensile and creep tests on 0.30% carbon cast steel and 9.39% carbon forged steel over temperature range of 400 to 650 C; cast steel has limiting creep stresses of 10, 8, and 4 ton per sq in. at 400, 450 and 497 C; forged steel has 13, 10, and 5 tons per sq in. at 400, 447, and 507 C.

STEEL CASTINGS

TEMPERATURE EFFECT. Mechanische Eigenschaften von niedriglegiertem Stahlguss bei erhoehten Temperaturen, F. Koerber and A. Pomp. Mitteilungen aus dem Kaiser-Wilhelm-Inst fuer Eisenforschung zu Duesseldorf v 13 n 20 report n 190 1931 p 223–36. Investigations of mechanical properties of steel castings at high temperatures, containing small amounts of various alloying elements; results shown in charts and tables; determination of elastic yield, tensile strength, elongation, etc., at various temperatures.

STOKERS

TRAVELING-GRATE. Betriebserfahrungen mit Unterwindzonenwanderrosten, H. Schlicke. Feuerungstechnikv 19 n 11 Nov 15 1931 p 175–7. Operating experiences with forced-draft traveling-grate stokers; advantages and disadvantages.

UNDERFEED. Zoned Air Control for Stokers Made Automatic, F. J. Chatel. Power v 75 n 4 Jan 26 1932 p 121–4. Individualized windboxes with individual control of air flow for distribution of air to each retort of underfeed stokers have been in operation for some time at Beacon Street heating plant of Detroit Edison Co.; similar system, with air-flow control made completely automatic, installed on stokers at Delray No. 3; improvements in operating efficiency are more noticeable in normal operation than during tests.

SWAGING MACHINES

APPLICATIONS. Machine Swaging as Modern Art—I and II, H. R. Le Grand. Am Mach v 76 n 5 and 6 Feb 4 1932 p 159–63 and Feb 11 p 208–11. Feb 4: Typical applications of swaging; construction and operation of rotary swaging machines and fixtures. Feb 11: Limits in tapers on solid and tubular work, examples of simple and difficult jobs, with production data and die design.

TUBES

BENDING. Rapid Forming of Multiple Bends in Tubing, J. E. Fenno. Machy (NY) v 38 n 6 Feb 1932 p 443–5. Design and operation of various types of fixtures; four bends made simultaneously; fixture of simple design for coiling tubing.

VIBRATIONS

DAMPING. Isolating Vibrations With Rubber, F. L. Haushalter. Product Eng v 2 n 12 Dec 1931 p 542–5. Design and constructional details of following: shear type mountings and compression pads and variations of amount of energy absorbed with thickness; temperature ranges of rubber.

WAGES

INCENTIVE PLANS. Practical Group Plan of Incentive Wage Payment, C. F. Scribner. Wood Working Industries v 11 n 1 Jan 1932 p 20–5 Reduced clerical expense, increased output, and simplicity of understanding by workers are natural results; organization of group bonus plan; group bonus plan compared with piece work and conditions which favor plan.

Profitable Wage Incentive Plans, H. E. Stocker. Matls Handling and Distribution v 7 n 3 Dec 1931 p 18–9 and 24. Application of wage incentive plans to materials handling operation; characteristics of specific applications.

WATER-COOLING SYSTEMS

TESTING. Abnahme von Rueckkuehlanlagen—Kritik des bisherigen Verfahrens, K. Lang. Waerme v 55 n 1 and 2 Jan 2 1932 p 1–4 and Jan 9 p 22–6. Critical discussion of German acceptance tests for water-cooling plants; empirical cooling diagram is developed, showing influence of various psychrometric differences for different cooling zones and air temperatures; investigations of methods of Otte and Kaissling show latter to be accurate and practical.

WATER PIPE LINES

DESIGN. Formula for Economic Hydraulic Gradient for Conduits, R. A. Hill. Eng News-Rec v 108 n 3 Jan 21 1932 p 85. Derivation of formula combining factors of present worth of loss in head, capital cost and relation of cost to size.

WATER POWER

CALCULATION. Calcul de l'énergie réalisable dans une installation hydraulique, en partant de la courbe de fréquence des débits, J. Calame. Bul Technique de la Suisse Romande v 57 n 17 Aug 22 1931 p 213–7. Computation of available power of hydraulic installation starting with stream hydrograph; theoretical mathematical discussion leading to derivation of graphic method.

WATER TREATMENT

LIME. Addition of Hydrochloric Acid to Water for Prevention of Scale in Water-Jackets and Condensers, H. Rusden and J. Henderson. Chem Met and Min Soc S Africa—J v 32 n 5 Nov 1931 p. 78–81 and (discussion) 81–3. Practice developed at by-products branch of Witwatersrand Co-operative Smelting Works, to neutralize alkalinity and destroy bulk of bicarbonate of lime; applicability of method to use in automobile radiators and household hot water systems.

WELDING

COPPER. Ueber den Einfluss von geringen Zusatzmengen in den Schweissdraehten auf die Schweissung des Kupfers, W. Geldbach. Autogene Metallbearbeitung v 24 n 21 and 22 Nov 1 1931 p 319–31 and Nov 15 p 335–45. Investigation of composition of welding rods on weldability of copper at laboratory of Technical University of Berlin; influence of phosphorus and aluminum in welding rods; effectiveness of fluxes; experiments with principal elements, particularly rare metals.

WELDS

STRENGTH. Der Einfluss der Arbeitsausfuehrung auf die Schrumpfspannungen einer Stumpfnaht, Jennings. Elektroschweissung v 2 n 12 Dec 1931 p 240–1. Tests showing influence of care exercised in arc welding; shrink stresses in obtuse seam are analyzed for six different manners of welding.

WIRE DRAWING

TUNGSTEN CARBIDE DIES. Development of Tungsten Carbide Die, L. C. Jacobson. Wire v 7 n 1 Jan 1932 p 18 and 26–8. Outline of difficulties surmounted in development of carbide die from its inception to its present use in drawing special shapes.